PROCEEDINGS
of the

Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA

ISSN 0078-2521

Volume 44 2008 Part 2
Completion of Vol 44

NSIS Student Science Awards 2007
Prize Winning Papers 201

Pseudoscience and the Paranormal: Obligations and Opportunities for Scientists and Science Educators
Jason Loxton 203

Turmeric: Not So Spicy After All
Robert G Harris 213

NSIS Presidential Address and Reports from Council Officers
Session 2006-2007 223

By-laws of the Nova Scotian Institute of Science (revised 2008) 231

NOV
5516
.b

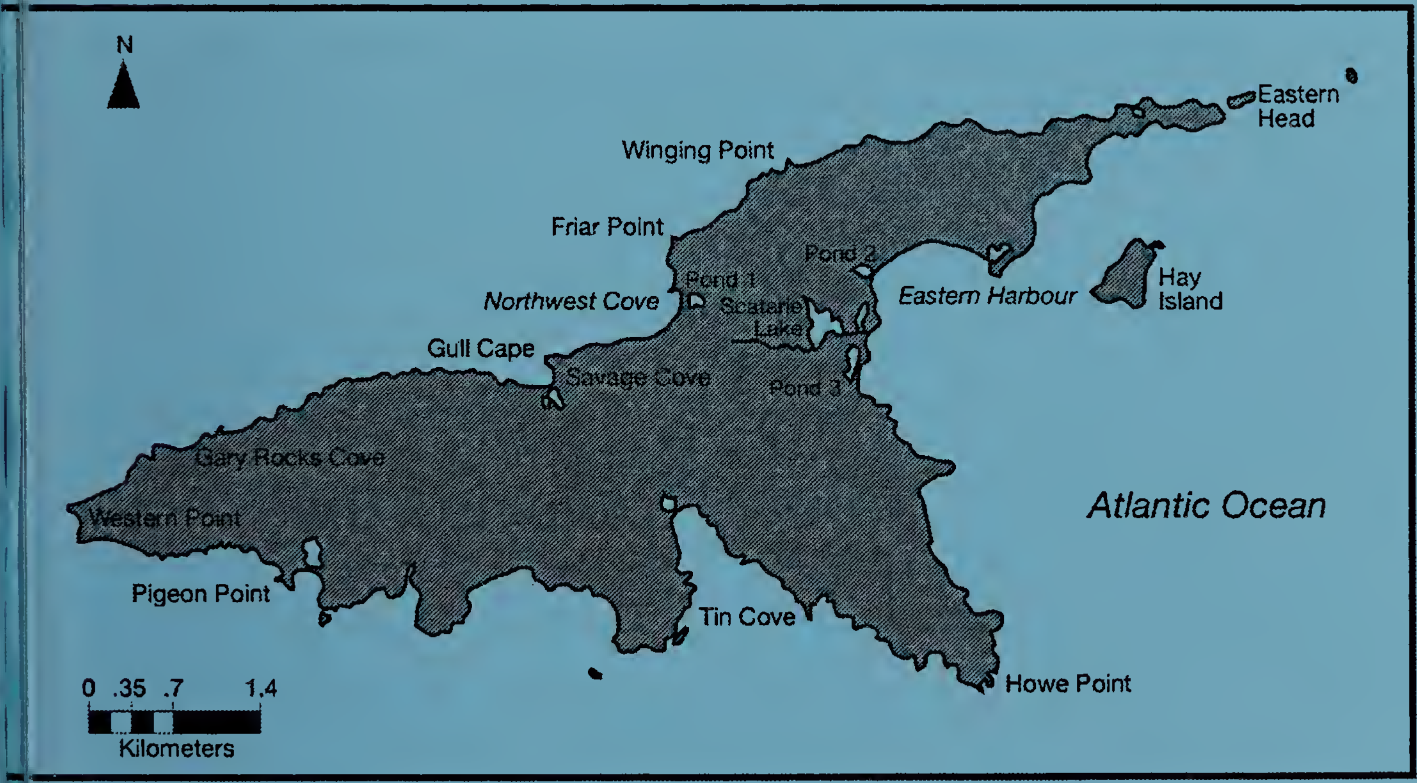
MCZ
LIBRARY
JAN 04 2011
HARVARD
UNIVERSITY

PROCEEDINGS
of the
Nova Scotian Institute of Science
HALIFAX, NOVA SCOTIA

V ume 45 2010 Part 1

SPECIAL ISSUE

SCATERIE ISLAND, NOVA SCOTIA



© Nova Scotian Institute of Science
Affiliated with Access Copyright, The Canadian Copyright Licensing Agency http://www.accesscopyright.ca
Date of Publication, July 2010

The Proceedings of the Nova Scotian Institute of Science are supported in part by a grant from the Department of Tourism Culture and Heritage, Government of Nova Scotia, with the support of the Nova Scotia Museum. Publication of articles, principally but not exclusively in the area of natural and engineering science, will be considered as well as papers emanating from studies in the health professions. Both regular issues and special issues devoted to topics of current Nova Scotian or Maritime interest are published.

Editorial Board

Peter G. Wells (Dalhousie University)	Editor
David H.S. Richardson (Saint Mary's University)	Associate Editor
Sarah Stevenson (Dalhousie University)	Production Editor
Roby Austin (Saint Mary's University)	Astronomy
Nola Etkin (UPEI)	Chemistry
Mike Dadswell (Acadia University)	Aquatic Ecology, Fisheries, Tidal Power
David Garbary (St. Francis Xavier University)	Plant Biology
Bruce Hatcher (Cape Breton University)	Marine science
Martha Jones (Cape Breton University)	Estuarine ecology, Invasive Species
Andrew Hamilton-Wright (Mount Allison University)	Artificial Intelligence
Eric Mills (Dalhousie University)	History of Science
Brian Petrie (BIO-DFO)	Oceanography
David W Piper (BIO-NR)	Geology
Martin Willison (Dalhousie University)	Conservation Ecology

Layout by Gail LeBlanc. Printing by Saint Mary's University

Manuscripts should be submitted electronically to the editor **(nsis@dal.ca)**. Membership of the NSIS is open to all those interested in Science and subscription details can be found on the Nova Scotian Institute of Science website **http://www.chebucto.ns.ca/Science/NSIS.** Members of the NSIS are not required to pay page charges but others are currently charged $25 per page to help defray the cost of publication **http://www.chebucto.ns.ca/Science/NSIS/index-new.html**

PROCEEDINGS
of the
Nova Scotian Institute of Science
HALIFAX, NOVA SCOTIA

Volume 45 2010 Part 1

CONTENTS

Managing the Scatarie Island Wilderness Area:
Introduction to issues for an island protected area
David Williams and Robert P. Cameron 1

Intertidal invertebrates of Scatarie Island:
A preliminary species inventory and habitat description
K. L. White, S. M. Townsend, A. S. Reynolds and E. B. Barrington 9

Beetles (Coleoptera) of Scatarie Island, Nova Scotia, Canada
Christopher G. Majka Sheena M. Townsend, Kathleen R. Aikens,
Jeffrey Ogden, A. Andrew M. Macdonald and
David B. McCorquodale 18

Freshwater and intertidal fishes of Scatarie Island, Nova Scotia
S. C. Mitchell 35

A checklist of vascular plants from Scatarie Island, Nova Scotia
Jonathan Ferrier, A. Andrew M. Macdonald and Barry R. Taylor 45

Lichens of Scatarie Island Wilderness Area
Robert P. Cameron, Wolfgang Maass and Frances Anderson 69

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 1-8

MANAGING THE SCATARIE ISLAND WILDERNESS AREA: INTRODUCTION TO ISSUES FOR AN ISLAND PROTECTED AREA

DAVID WILLIAMS[1] AND ROBERT P. CAMERON*[2]
[1]Nova Scotia Environment, Protected Areas Branch
295 Charlotte Street, PO Box 714
Sydney, Nova Scotia B1P 6H7

[2]Nova Scotia Environment
PO Box 697
Halifax, Nova Scotia B3J 2T8

Scatarie Island is a 1500 ha island off the coast of Cape Breton which contains a variety of habitats and a diversity of plants and animals. Over the last 300 years the island has seen human settlement, use by fishermen and management as a Wildlife Management Area. In 1998 the island was designated as a Wilderness Area under the Wilderness Areas Protection Act. The island's designation recognizes both its significant ecological values and wilderness recreation potential. Suitable management strategies for Scatarie Island Wilderness Area must give proper consideration to protecting those ecological values for which the island was originally designated. Current visitors to the island include all-terrain vehicle drivers and sea kayakers, both of which offer different management challenges. Climate change and possible effects of air pollution from adjacent industrial areas are other issues for the management of the protected area. In order to better understand the biota of the island and provide an adequate information base for the management of the protected area, a 4 day bioblitz consisting of 15 scientists and students was conducted in 2005. This bioblitz consisted of a biological survey in a variety of disciplines over the 4 days. More than 180 species were documented during this survey and at least 8 species had not been reported previously for Nova Scotia.

L'île Scatarie, d'une superficie de 1 500 ha, se trouve près de la côte du CapBreton. Elle renferme plusieurs types d'habitats et abrite diverses espèces végétales et animales. Au cours des trois derniers siècles, l'île a été habitée, utilisée par les pêcheurs et considérée comme une aire de gestion de la faune. En 1998, elle a été désignée réserve faunique en vertu du Wilderness Areas Protection Act. Cette désignation atteste de l'importance des atouts écologiques de l'île mais aussi de son potentiel pour les activités récréatives en pleine nature. Des stratégies de gestion adéquates doivent être mises en place pour la réserve faunique de l'île Scatarie afin de protéger les atouts écologiques qui ont valu à l'île cette désignation. L'île est actuellement fréquentée, entre autres, par des utilisateurs de véhicules tout terrain et des adeptes du kayak de mer, deux catégories d'utilisateurs qui posent des défis différents en matière de gestion. Le changement climatique et les effets éventuels de la pollution atmosphérique provenant des zones industrielles

---

* Author to whom correspondence should be addressed.
Email: camerorp@gov.ns.ca

adjacentes posent d'autres types de problèmes pour la gestion de la zone protégée. Afin de mieux comprendre le biote de l'île et de constituer une base de renseignements adéquate pour la gestion de la zone, on a effectué, en 2005, un « bioblitz » de 4 jours regroupant 15 scientifiques et des étudiants. L'opération a pris la forme d'études biologiques dans diverses disciplines. Plus de 180 espèces ont ainsi pu être documentées, dont 8 qui n'avaient jamais été signalées auparavant en NouvelleÉcosse.

INTRODUCTION

Scatarie Island is approximately 1,500 hectares in size and lies off the eastern extreme of Cape Breton Island (Fig 1).

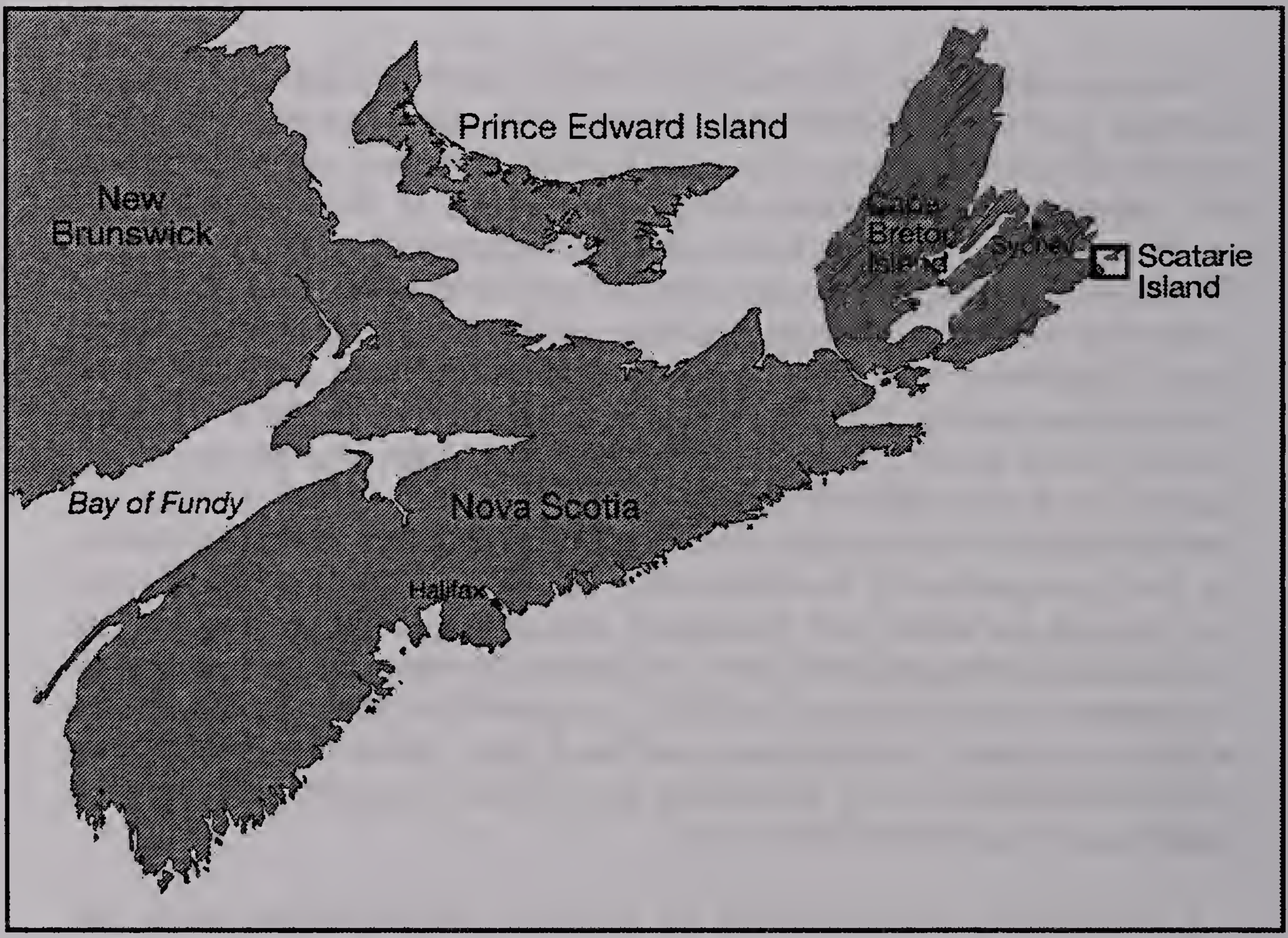


Fig 1 Location of Scatarie Island within Nova Scotia.

Exposure to harsh marine climatic conditions has combined with thin soils and a hilly, undulating terrain to create a patchwork of wetland and barren complexes interspersed with stunted coniferous forests of balsam fir and white and black spruce. A single, small freshwater lake is located on the eastern half of the island. Brackish ponds or lagoons are commonly found behind barrier beaches in many of the coves and inlets (Fig 2).

The island boasts a unique and rich diversity of plant and animal species, and the surrounding waters have historically supported lucrative fisheries. A host of coastal, marine and migratory bird species utilize the islands varied habitats and resources.

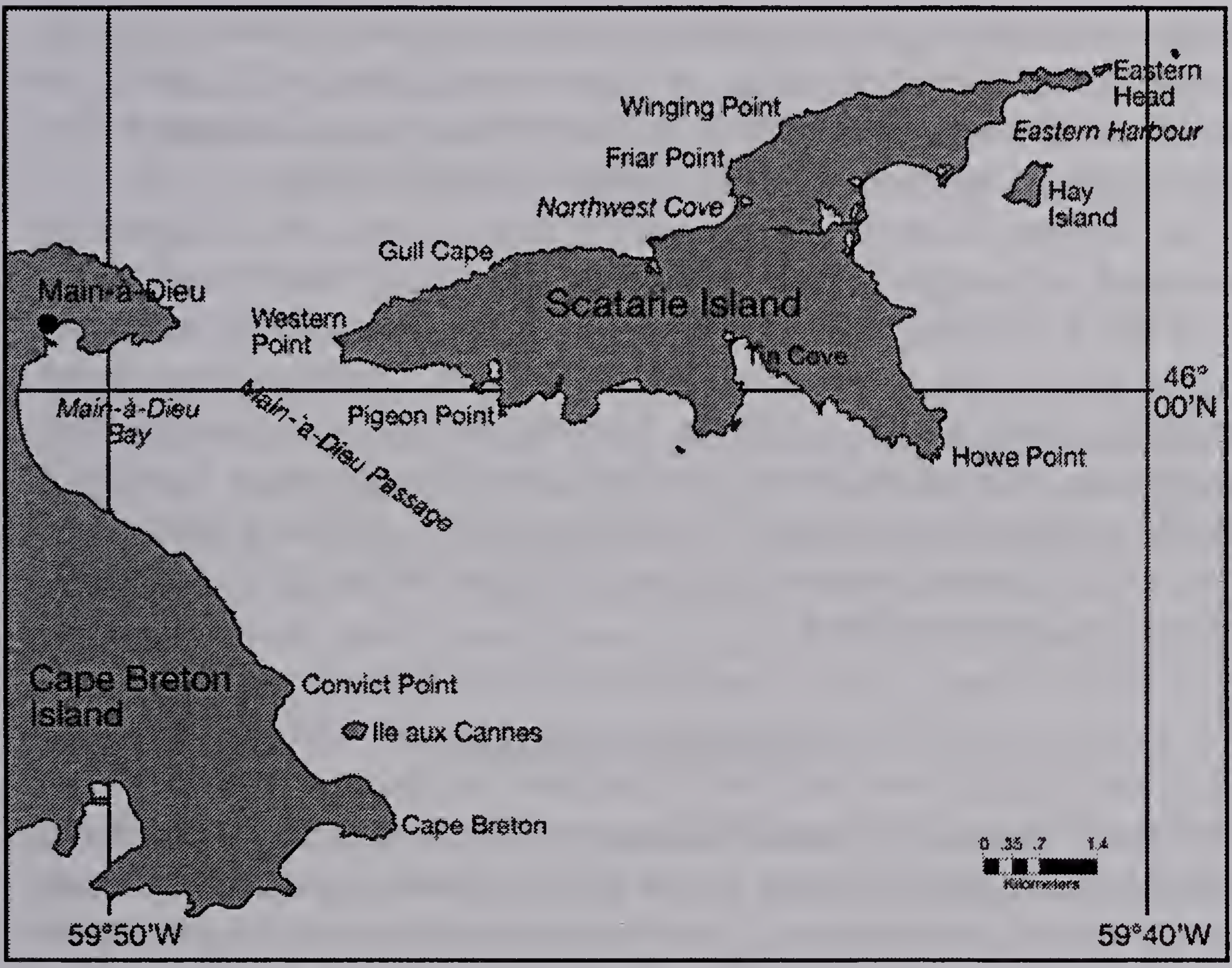


Fig 2 Scatarie Island, Nova Scotia.

RECENT HISTORY

In the early 1700's, French fishing fleets sought out the sheltered harbours and cobble beaches on the eastern end of the island to dry their catch of cod prior to exporting it to Europe. An abundance of fish soon led to the establishment of a small, permanent settlement in the area of Eastern Harbour. This community persisted until the capture and destruction of the French fortress at Louisbourg in 1758 (Chrestien 2001). Resettlement by several English and Irish families, primarily from communities in Newfoundland, soon followed the establishment of a manned lighthouse and marine life-saving stations on the island in the 1830's. Through the 19th and early 20th centuries, fishermen and their families continued to maintain homes on the island, processing their catches and often caring for a few livestock and a small vegetable garden. Although most building materials were imported from elsewhere, the local forests supplied fuel as well as wood and materials for their traps and drying racks. Diets were supplemented by ducks and other sea birds as well as seals in the spring. As the winters were long and difficult, and communities grew on nearby Cape Breton Island, settlements on Scatarie became seasonal residences. With the introduction of cold storage and centralized fish processing facilities, permanent settlement was largely abandoned. The last permanent residents on record were the lighthouse keeper and his family. They left the island in 1987 when the light at Eastern Head was automated (The Nova Scotia Lighthouse Preservation Society 2006).

The former Nova Scotia Department of Lands and Forests introduced willow ptarmigan and arctic hare from Newfoundland in the 1970's (Godfrey 1971). Although small populations persisted on the island for some time, no confirmed sightings have been recorded since 1986. In 1976, Scatarie Island and those waters within one mile of its shoreline were designated as a provincial wildlife management area. This designation permitted hunting for deer and migratory waterfowl but all other forms of hunting and trapping were prohibited.

CURRENT STATUS

In 1998, the island classification was raised from a provincial wildlife management area to be the Scatarie Island Wilderness Area under the Wilderness Areas Protection Act administered by the Nova Scotia Department of Environment and Labour. This legislation prohibits industrial and commercial development. Disturbance to plant and animal communities is restricted to specific activities permitted under the Act such as scientific research and wilderness hiking trail development. The island's designation recognizes both its significant ecological values and wilderness recreation potential, including the following features:

- One of Nova Scotia's largest coastal islands displaying a relatively high level of ecological integrity despite past human use and settlement;
- Ecological representation of the Louisbourg Cliffs Natural Landscape;
- Large number of rare vascular plants including arctic / alpine species;
- Diversity of coastal and marine birds (breeding and / or frequent visitors) including whimbrel, Leach's storm petrel, great cormorant, common and arctic terns, ruddy turnstone and common eider;
- Home to one of Canada's rarest birds, the Bicknell's thrush;
- Provincially significant breeding colony of grey seals;
- Nesting colony of an estimated 70,000 Leach's storm petrel;

- Spectacular coastal scenic viewing opportunities combined with high-quality sea kayaking and coastal hiking / camping potential (see Godfrey 1971, White 2002, Cameron 2004, and Pronych & Wilson 1993).

BIOBLITZ 2005

Despite the status of the island and the significance of the flora and fauna found there, there has been little ecological research conducted previously. Protected Areas Branch of Nova Scotia Environment, invited 15 scientists and students in 7 disciplines to conduct inventories on the island between 8 and 11 August, 2005. Inventories took place over three days in as varied areas of study as vascular plants, fish and invertebrates. Four organizations took part: 2 universities and 2 governmental. The following papers are the results of these efforts and represent the most significant published ecological data for this remarkable island. Over 180 species have been documented during this survey and at least 8 species have not been reported previously for Nova Scotia.

The Scatarie Island bioblitz is the second of several bioblitzs conducted by the Protected Areas Branch of Nova Scotia Environment. A main objective of a bioblitz is to increase the knowledge of a little studied, protected area. The bioblitz concept provides the Protected Areas Branch with outside expertise and at the same time provides opportunities for specialists to interact. Volunteers and students participate and gain a variety of knowledge on a diverse array of species.

MANAGEMENT ISSUES

Suitable management strategies for the Scatarie Island Wilderness Area must give appropriate consideration to protecting those ecological values for which the island was originally designated. At the same time, they must recognize the importance of the islands cultural heritage and the strong community and family ties that still exist among residents of nearby towns and villages on Cape Breton Island. As an example of the latter, the fishermen of the village of Main-a-Dieu still ferry residents and visitors alike out to Northwest Cove every year for a community picnic and religious observances. These cultural links help to promote a stronger sense of community ownership or stewardship for the protected area, which in turn, can facilitate appropriate management and preservation of its resources. Even though much of the island is owned and administered by the Province, there are six small land parcels (totalling some 17 hectares) owned by either the Federal government (2) or private individuals (4). The ownership rights of these landowners, including the right of access, must be recognized and accommodated in any management scenario.

The use of off-highway vehicles, particularly ATV's, has grown in popularity across the province, and unregulated use of these vehicles raises many questions related to their possible impacts on the island's ecosystems. During the bioblitz, several unauthorized ATV trails were noted, particularly in the area between Northwest Cove and Eastern Head. The trails were characterized by varying levels of damage to ground vegetation. In extreme cases, the vegetative cover was completely removed from the area of wheel tracks resulting in exposed humus layers, mineral soil or bedrock. The loss of vegetation from even moderate slopes of 10 percent was often accompanied by surface erosion of organic matter and finer soil particles. Concerns also exist over possible impacts to resident populations of nesting and migrating birds as well as sensitive wetlands. The situation is aggravated to some degree by the fact that active enforcement of existing restrictions on vehicle use and monitoring of compliance are severely limited by the difficulties faced in accessing the island. Fortunately, access issues are also a challenge for potential vehicle users – a possible contributing factor to the healthy state of many of those ecosystems visited during the bioblitz.

An increasing interest on the part of sea kayakers and the ecotourism sector is leading to higher levels of human use on a limited number of suitable resting / camping sites along the coast. Consequently, the need is increasing for effective educational initiatives to raise the level of public awareness and adoption of low-impact recreational activities, as are the requirements for ongoing research and monitoring directed towards assessing actual levels of use and possible ecosystem degradation.

Scatarie Island faces many of the broader issues affecting coastal ecosystems throughout the world. Marine and coastal environments have suffered the event-specific as well as cumulative effects of pollution for many years (Niemi 2004). Indeed, lichenologists from the bioblitz have noted a significant lack of air pollution-sensitive lichens suggesting possible air pollution impacts on Scatarie's ecosystems. Of potentially greater threat to the island's ecological integrity is the current trend of global warming resulting in climatic changes. Rising air temperatures could have a significant, direct effect on the composition of terrestrial ecosystems, particularly where species are at the extreme limits of their natural ranges. For example, a change from boreal ecosystems to more temperate ecosystems is predicted for Atlantic Canadian Parks (Suffling & Scott 2002). If such changes occur, rare arctic-alpine plants found on the island may be affected. While some native species face the possibility of being forced out by changing site conditions, non-native species may become established, possibly compromising the viability of native populations even more. Godfrey (1971) identified several species of non-native plants; given the island's history of human use, this is not surprising. Parks Canada has identified sea level rise as the greatest potential threat to Atlantic Canadian Parks (Suffling & Scott 2002). Warmer waters, combined with rising sea levels and possible changes in ocean currents, will likely affect marine ecosystems, resulting in changes to the numbers, distribution and migratory patterns of coastal and marine species. In order to assess the extent of these and the other changes that could occur, it is critical that research be undertaken to collect basic population data for existing plant and animal communities on Scatarie Island. Inventories like those conducted during the bioblitz give a better understanding of the number and species of plants at the southern extent of their known range and provide a baseline for measuring future climate change. The identification of rare or sensitive species also assists in the development of ecologically appropriate strategies for managing public use of the island for wilderness recreation and other outdoor pursuits.

REFERENCES

Cameron RP (2004) Resources guide and ecological atlas: For conducting research in Nova Scotia's Wilderness Areas and Nature Reserves. Technical Report 0401, Protected Areas Branch, Nova Scotia Environment and Labour, Halifax, NS.

Chrestien J-P (2001) Archaeological survey and testing of eighteenth-century fishing properties on Scatarie Island (Nova Scotia). Report for the year 2000, Canadian Museum of Civilization, Ottawa, ON.

Godfrey AP (1971) A trial introduction of willow ptarmigan (*Lagopus lagopus* Alleni) to Nova Scotia. MSc thesis, Acadia University, Wolfville, NS.

Niemi D (2004) Emissions related to acid deposition in North America. In: Canadian acid deposition: Science assessment and summary of key results. Environment Canada, Ottawa, ON.

Pronych G, Wilson A (1993) Atlas of rare vascular plants in Nova Scotia. Curatorial Report 78, Nova Scotia Museum of Natural History, Halifax, NS.

Suffling R, Scott D (2002) Assessment of climate change effects on Canada's National Park system. *Environmental Monitoring and Assessment* 74(2):117-139.

The Nova Scotia Lighthouse Preservation Society (2006) http://www.nslps.com/lights/lighthouse_page_01.asp?ID=359&LL=212.

White K (2002) 2002 study of established and potential important bird areas of Cape Breton. Atlantic Coastal Action Program, Sydney, NS.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 9-17

INTERTIDAL INVERTEBRATES OF SCATARIE ISLAND: A PRELIMINARY SPECIES INVENTORY AND HABITAT DESCRIPTION

K. L. WHITE[1]*, S. M. TOWNSEND[2], A. S. REYNOLDS[1]
AND E. B. BARRINGTON[1]
[1]Cape Breton University
1250 Grand Lake Road
Sydney, Nova Scotia B1V 6L2

[2]Department of Zoology, University of Otago
340 Great King Street, P.O. Box 56
Dunedin, New Zealand

As intertidal habitats of offshore islands remain relatively undocumented compared with their mainland counterparts, we conducted a survey of intertidal habitats on Scatarie Island, Nova Scotia. Two sites at Northwest Cove on the western side of the island and two sites at Eastern Harbour on the eastern side were classified in terms of their backshore and substrate characteristics. Infauna were collected within quadrates at each site and identified to species when possible. Additional visual searches of the wrack line, intertidal and subtidal zones were conducted to supplement the species inventory. Our survey represents a starting point for the characterization of intertidal habitats and inventory of intertidal fauna within this Protected Wilderness Area. Twenty-two species of marine invertebrates, including sponges, molluscs, echinoderms, arthropods and bryozoans, were identified. The majority of these were collected on the eastern side of the island within a relatively well protected area characterized by rock pools. Sites examined on the western side of the island had lower faunal diversity and less accumulated macroalgae. Differences in the subtidal depth, slope, dominant substrate type and exposure may offer a partial explanation for this finding.

Les habitats intertidaux des îles du large demeurent relativement peu documentés comparativement à ceux du continent. C'est pourquoi nous avons mené une étude des habitats intertidaux de l'île Scatarie, en Nouvelle-Écosse. Nous avons classé deux sites de l'anse Northwest, dans la partie ouest de l'île, et deux sites de la baie Eastern, dans la partie est, en fonction des caractéristiques de leur arrière-côte et de leur substrat. Nous avons quadrillé chaque site et recueilli, dans les carrés ainsi délimités, des organismes benthiques que nous avons classés par espèces dans la mesure du possible. D'autres recherches visuelles dans les cordons de goémon et les zones intertidale et infralittorale ont été effectuées pour enrichir l'inventaire des espèces. Notre étude constitue un point de départ pour la caractérisation des habitats intertidaux et l'élaboration d'un inventaire de la faune intertidale dans cette région sauvage protégée. Vingt-deux espèces d'invertébrés marins, dont des éponges, des mollusques, des échinodermes, des arthropodes

---

* Author to whom correspondence should be addressed.
Email: Kellie_White@cbu.ca

et des bryozoaires, ont été identifiées. La majorité de ces espèces ont été recueillies dans la partie est de l'île, dans un secteur relativement bien protégé caractérisé par des bassins rocheux. Dans les sites étudiés du côté ouest de l'île, la diversité faunique et les accumulations de macroalgues étaient moindres, ce qui peut s'expliquer partiellement par les différences dans les profondeurs infralittorales, dans la pente, dans le type dominant de substrat et dans l'exposition aux éléments.

INTRODUCTION

The shoreline of Scatarie Island includes habitats ranging from bedrock cliffs to cobble, gravel and sandy beaches, which are typical of habitats over the entire Atlantic coast of Nova Scotia. These habitats have been studied intensively throughout the Gulf of Maine and the Canadian Maritimes (e.g., Bertness 1999, Bousfield & Leim 1960, Ginn et al. 1998, Lubechenco & Menge 1978, Metaxas et al. 1994, Roman et al. 2000). However, the intertidal regions and associated fauna of offshore islands such as Scatarie are largely undocumented.

As illustrated in the introduction to this series, Scatarie is an uninhabited island, located approximately 1 km off the east coast of Cape Breton Island, Nova Scotia and is currently protected under the Nova Scotia Wilderness Areas Protection Act. The marine invertebrate species occurring within this area represents an important part of the island's ecosystem.

We collected invertebrates within the intertidal zone of Scatarie, the area of shore covered and uncovered by the tides. The type of marine invertebrate fauna occurring within this habitat is largely related to tide exposure time and substrate, which are in turn related to tidal range, wave energy and shore source materials (Bertness 1999). The tidal range at Scatarie Island (as estimated from the closest gauging station at Louisburg) is 1.1 m at the lowest neap tide to 1.8 m at the highest spring tide (Canadian Hydrographic Service 2003). The shoreline of the island is dominated by cliffs of Precambrian volcanic rocks which include pyroclastic lapilli tuffs and basalt flows (Barr et al. 1996). Beaches have developed along the shores of the island's bays as a result of wave action, resulting in turn in the rounding and sorting of the source materials derived from these cliffs and from the Quaternary (glacial) till which blankets the island (Roland 1982).

This study was part of the 'bioblitz' (see series Introduction) and was undertaken as the first step toward a description of Scatarie's intertidal habitats and an inventory of the marine invertebrates occurring within and in waters adjacent to these habitats.

METHODS

As the intertidal habitat occurring at the base of Scatarie's cliffs is difficult to access, our study focused on Scatarie's beaches and one accessible rocky shore on the eastern end of the island. In the first week of August, 2005 detailed habitat characterizations were made along four 100 m shore sections on two of Scatarie Island's largest beaches: Northwest Cove on the western side of the island and Eastern Harbour on the eastern side (Fig 1). These sampling sites were chosen to represent variations in the island's beach habitat resulting from variations in wave energy and associated substrates. Within the 100 m shore sections, a variety of habitat variables were recorded including backshore characteristics. For this study, the backshore was defined as starting at the top of the shore where vegetation first occurs and to 30 m landwards. Dominant vegetation and land forms were noted within this area. Within the intertidal zone, at each 100 m shore site, habitat characteristics including size of dominant sediment (Wentworth 1922, Cummins 1962) and percent algal cover were visually assessed using six haphazardly placed 1 m^2 quadrats, three at the mid and three at the low tide level. Infauna was also sampled within each of these six quadrats. Substrate was removed with a shovel to a depth of 15 cm within a 0.25 m^2 area located at the lower righthand corner of each 1 m^2 quadrat. The substrate was sieved through a 500μm sieve and examined for macroinvertebrates. In July of 2006 additional marine invertebrate collections were made during visual searches of the entire shoreline of Northwest Cove (~ 2 km), East-

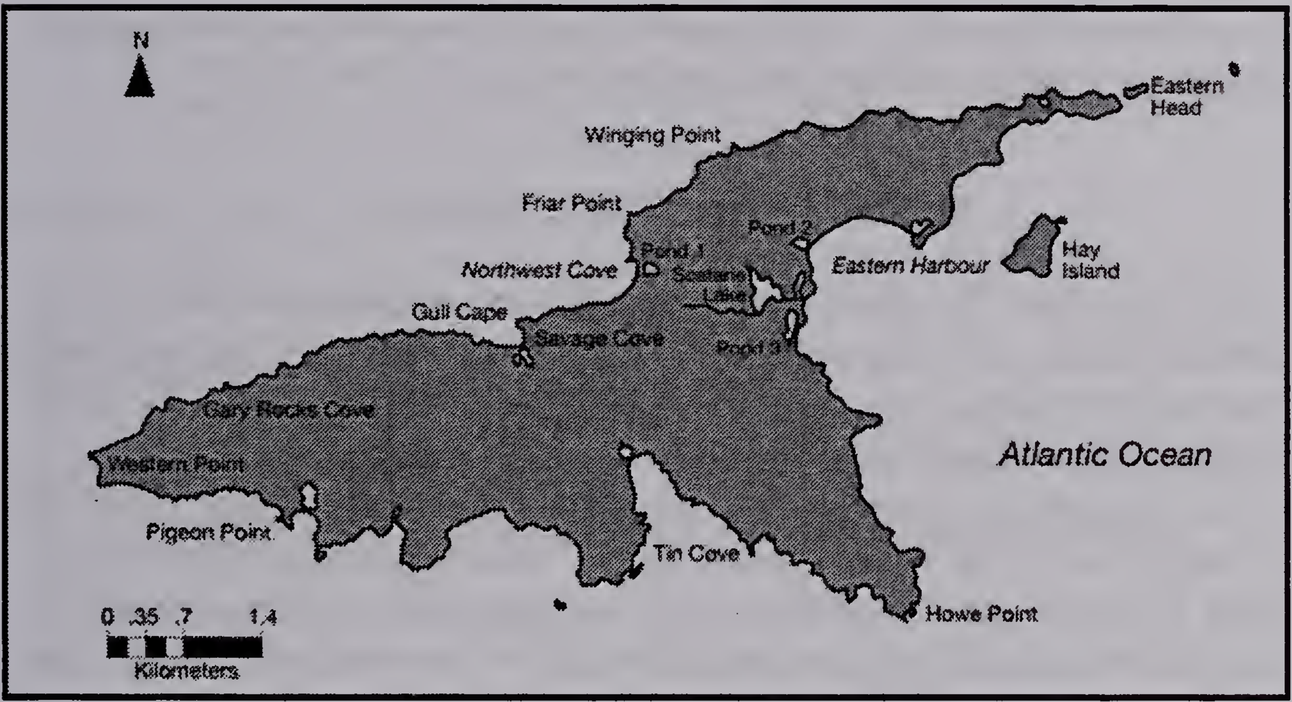


Fig 1 Scatarie Island, Nova Scotia

ern Harbour (~ 2.5 km) and the rocky shore and tide pools of Rock Point Beach (~ 1 km) at the north eastern tip of the island (Fig 1). Particular attention was paid to wrack line debris as this tends to accumulate dead specimens and shell molts (exuvia) representative of the living invertebrate community in the adjacent intertidal and subtidal areas (Kidwell 2002). Invertebrates were either identified in the field or brought to the laboratory for further study. Live specimens brought back to the laboratory were preserved in 70% ethanol; identification and nomenclature were based on Gosner (1979) and Weiss (1995). Voucher specimens were sent to the Nova Scotia Museum of Natural History to serve as permanent, verifiable records of species identifications.

RESULTS AND DISCUSSION

We identified 22 species of marine invertebrates within the intertidal areas of Scatarie Island (Table 1). Eleven species were collected live while the remaining half were represented by shell molts or dead specimens found in wrackline debris.

The majority of species were found on the south eastern side of the island at Rock Point Beach and Eastern Harbour. The backshore at the Rock Point site was dominated by crowberry shrub (*Empetrum nigrum*) and exposed rock. The intertidal area was rocky with rock pool formations and a small (~ 500 m) beach in the adjacent bay that was dominated by gravel and coarse sand. Rock Point Beach is protected from the southeast and south winds that prevail in the summer by a small island (Hay Island) less than 1 km off its shoreline. On the other hand, the majority of shore at Eastern Harbour is more exposed to the full force of the summer winds and associated waves. The backshore at the Eastern Harbour site is comprised of several coastal lagoons (barachois) surrounded by a treed bog. The shore itself was characterized by an accumulation of cobble just above the high tide mark typical of high energy (waves, swell, storms) glacial till shorelines (Davis & Browne 1996). Middle and lower intertidal zones were dominated by coarse, poorly sorted, gravelly sand.

Live Northern Rock Barnacle (*Balanus balanoides*), Blue Mussel (*Mytilus edulis*) Common Periwinkle (*Littorina litorea*) and Smooth Periwinkle (*Littorina obtusata*) were observed attached to rock outcrops and cobble within the middle and lower intertidal areas at Rock Point. Live Sandhoppers (*Orchestia gammarellus*) were found within the upper shore wrackline debris at both Rock Point and Eastern Harbour beach along with shell molts from Lobster (*Homarus americanus*) and Rock Crab (*Cancer irroratus*). Empty shells

Table 1 Preliminary checklist of marine invertebrates of Scatarie Island, Nova Scotia

PORIFERA
Bread Crumb Sponge, Halichondria panicea (Pallas, 1766)
Eye and Finger Sponge, Haliclona oculata (Pallas, 1766)

MOLLUSCA
Common Periwinkle, *Littorina littorea* (Hamer, 1920)*
Smooth Periwinkle, *Littorina obtusata* (Linnaeus, 1758)*
Atlantic Dog Whelk, *Nucella lapillus* (Linnaeus, 1758)*
Waved Whelk, *Buccinum undatum* (Linnaeus, 1758)*
Blue Mussel, *Mytilus edulis* (Linnaeus, 1758)*
Atlantic Surf Clam, *Spisula solidissima* (Say, 1822)
Tortoise Shell Limpet, *Tectura testudinalis* (Müller, 1776)
Wrinkled Rock Borer, *Hiatella arctica* (Linnaeus, 1767)
Horse Mussel, *Modiolus modiolus* (Linnaeus, 1758)

ECHINODERMATA
Green Sea Urchin, *Strongylocentrotus droebachiensis* (Müller, 1776)
Purple Sea Star, *Asterias vulgaris* (Verrill, 1866)*

POLYCHAETA
Spiral Tube Worm, *Spirorbis spirillum* (Linnaeus, 1767)

ARTHROPODA
Northern Rock Barnacle, Balanus balanoides (Linnaeus, 1767)*
Scud, *Gammarus* sp.*
Sand Hopper, *Orchestia gammarellus* (Pallas, 1766)*
Lobster, *Homarus americanus* (Milne-Edwards, 1837)
Green Crab, *Carcinus maenas* (Linnaeus, 1758)
Rock Crab, *Cancer irroratus* (Say, 1817)
Baltic Isopod, *Idotea balthica* (Pallas, 1772)*

BRYOZOA
Lacy Bryozoa, *Electra pilosa* (Linnaeus, 1767)*

* Denotes species observed live; all others were identified from empty shells, molt exuvia or dead individuals collected in wrack debris.

of Waved Whelk (*Buccinum undatum*), Atlantic Surf Clam (*Spisula solidissima*), Green Sea Urchin (*Strongylocentrotus droebachiensis*), Horse Mussel (*Modiolus modiolus*), Tortoise Shell Limpet (*Acmaea testudinalis*), and Wrinkled Rock Borer (*Hiatella arctica*) as well as remains of Eyed Finger Sponge (*Haliclona oculata)* and Bread Crumb Sponge (*Halichondria panicea*) were also observed washed up in the wrackline at both these sites. Waved Whelk egg casings were observed in the wrackline at Eastern Harbour.

The shore along the north western side of the island was noticeably different. The backshore along the inner bay of Northwest Cove Beach lacked the cobble “storm beach” that was a prominent feature of the beaches on the eastern side of the island. Here the backshore was characterized by low (1 – 1.5 m) eroding dunes dominated by the dune grass *Elymus mollis*. Towards the heads of the bay, the backshore consisted of rocky cliffs between 2 and 4 m high. The middle and lower intertidal area of North Cove beach was dominated by poorly sorted coarse sand and gravel substrate. Rock Crab molts, empty shells of Common Periwinkle and Atlantic Dog Whelk (*Nucella lapillus*) as well as Bread Crumb and Eyed Finger Sponge were collected in wrack line debris at North Cove Beach. Living specimens of Purple Sea Star (*Asterias vulgaris*), Blue Mussel, and Northern Rock Barnacle were found at the lower intertidal. A single empty shell of the invasive species Green Crab (*Carcinus maenas*) was found along the top of the cliffs at Winging Point. This was probably dropped by a gull. Given the distance to the mainland, it seems probable that the live Green Crab was plucked from the shores of Scatarie.

The flora of Scatarie Island's shoreline was not examined in any detail for this study, but the lack of macroalgae at Northwest Cove and the dense accumulation of macroalgae within both the subtidal and intertidal at Eastern Harbour was noteworthy. Differences in near-shore depths and substrate may account for the variation observed. Eastern Harbour is characterized by a shallow sloping subtidal that is less than 5 m deep between 1-2 km from the shoreline; whereas the shore at Northwest cove drops off steeply, with subtidal water depths reaching over 15 m only 200 m from shore and over 25 m at around 1 km from shore (Nautical Data International 2006). The numerous rocky outcrops visible within the subtidal region of Eastern Harbour also indicate a hard bottom substrate that would be optimal for macroalgal attachment. The gale force winds and storm surge associated with Tropical Storm Franklin that passed south of the island the week prior to our 2006 survey of the island may have caused the large accumulation of macroalgae at Eastern Harbour. Serrated Wrack (*Fucus serratus*) formed the bulk of the macroalgae observed. Sugar Kelp (*Laminaria saccharina*), Irish Moss (*Chondrus crispus*), Bladder Wrack (*Fucus vesiculosus*), *and* Knotted Wrack (*Ascophyllum nodosum*) were also present. An abundance of amphipods (unidentified *Gammarus* sp.) were observed living underneath these algal mats and Lacy Bryozoa (*Electra pilosa*) and Spiral Tube Worm (*Spirorbis spirillum*) were found encrusted on both Serrated Wrack and Irish Moss.

No living invertebrates were found within any of the beach sediment samples taken on Scatarie. The only endobenthic (living within the sediment) organism identified on the island was the Atlantic Surf Clam. Adults of this bivalve tend to prefer the type of high energy shores with coarse-grained sand and gravel sediment that occur on Scatarie Island (Fay et al. 1983). However, most other burrowing animals typical of this region require lower energy habitat with finer sediments, which could account for their absence from our Scatarie sample sites.

Ten of the marine invertebrate species reported in a survey done in the Bras d'or Lakes of Cape Breton (Tremblay 2002) were also found during our survey of Scatarie. However, sixteen species reported by Tremblay (2002) were not found at our Scatarie sampling sites and twelve species of marine invertebrate found at Scatarie were not recorded in the Bras d' Or Lakes study. Some of the differences in taxa between these two sites are expected based on habitat differences. There is reduced salinity (21 – 23 ppt) within much of the Bras d'Or Lakes compared with the open ocean salinities (31 ppt) of the water surrounding Scatarie Island (Davis & Browne 1996) and the shores of Bras d'Or are far more protected from wave energy and ice scour in comparison with Scatarie. Five of the species reported by Tremblay (2002) (not seen in our samples on Scatarie) are associated with protected bay habitats (e.g. *Crassostrea virginica*, *Mya arenaria*, *Ensis directus)*.

Differences in sampling methods between the two studies also likely explain differences in taxa reported. Tremblay's (2002) sampling efforts focused on the subtidal (via trawls and lobster traps) whereas our study of Scatarie focused on intertidal areas and wrackline debris. Our sampling method was likely biased against taxa that do not live intertidally or have visible shell molts or shell remnants that collect in the wrackline. This may explain the absence of shrimp species such as *Pandalus montagui* and *Crangon septempinosus* and the echnionderms *Solaster* sp. and Sea Cucumber from our Scatarie sampling. These species were found in the Bras d'Or Lakes study (Tremblay 2002).

The marine invertebrate species identified on Scatarie Island are consistent with Boreal-Arctic marine fauna characteristic of rocky shore benthic habitats of the region (Bousfield & Thomas 1975). Metaxas et al. (1994) surveyed exposed rocky shores near Halifax, Nova Scotia and reported nine macroinvertebrate species, six of which we also reported for Scatarie Island (*Littorina litorea*, *Littorrina obtusata*, *Nucella lapillus*, *Mytilus edulis*, *Strongylocentrotus droebachiensis,* and *Acmaea testudinalis*). Their sampling focused exclusively on live tide pool specimens which would account for the absence from their species list of the subtidal species found in our study (e.g. *Buccinum undatum*, *Homarus americanus*). These species were represented by shell molts or empty shells in our Scatarie samples.

Differences between islands and the mainland have been described and identified mainly for terrestrial organisms (e.g. Sol

2000) with less effort devoted to marine invertebrates. It is possible that differences between islands and the mainland exist because of environmental differences between the two regions. Historical events, physical processes such as local oceanography and climate, natural and anthropogenic disturbance and biotic interaction, may in principle, contribute to differences between the environmental conditions of islands and mainland shores. Further study comparing islands to the mainland may reveal that differences in these environmental conditions result in differences in intertidal species assemblages. Our study represents only a very preliminary inventory of the marine species present on and around Scatarie Island. Continued examination of the island for additional intertidal and subtidal species (both floral and faunal) will provide a more complete database for comparison of the marine species assemblages of the island with those of nearby mainland areas. Such surveys can also be useful in identifying new invasive species that may be a threat to the island as well as identifying species that may be of conservation interest.

Acknowledgements. The authors wish to acknowledge the Atlantic Coastal Action Program of Cape Breton and Cape Breton University for providing the equipment and logistical support required for the field work. Keith Campbell and his colleagues provided invaluable transport to and from the island. Bruce Hatcher's zodiac "taxi service" as well as other support was also especially helpful. Margi Amos, Jennifer Easterly and Emily Mizier-Barre assisted with field work. Comments by David McCorquodale and Fenton Isenor were most useful for improving the manuscript. Finally we would like to thank Rob Cameron for inviting us to take part in the bioblitz project.

REFERENCES

Barr SM, White CE, Macdonald AS (1996) Geology, southeastern Cape Breton Island, Nova Scotia. Map 1853, scale 1:100 000. Geological Survey of Canada, Ottawa, ON.

Bertness MD (1999) The ecology of Atlantic shoreslines. Sinauer Associates Inc, Sunderland, MA.

Bousfield EL, Leim AH (1960) Fauna of the Minas Basin and Minas Channel. National Museums of Canada Bulletin 166:1-30.

Bousfield EL, Thomas MLH (1975) Postglacial changes in distribution of littoral marine invertebrates in the Canadian Atlantic region. *Proceedings of the Nova Scotian Institute of Science* 27 (Supplement 3):47-60.

Canadian Hydrographic Service (2003) Canadian Tide & Current Tables: Volume 1 Atlantic Coast and Bay of Fundy. Department Fisheries and Oceans Canada, Ottawa, ON.

Cummins KW (1962) An evaluation of some techniques for collection and analysis of benthic samples with special emphasis on lotic waters. *American Midland Naturalist* 67(1):477-504.

Davis DS, Browne S (1996) The natural history of Nova Scotia, Vol.1. Topics and habitats, Rev. ed. Nova Scotia Museum and Nimbus Publishing, Halifax, NS.

Fay CW, Neves RJ, Pardue GB (1983) Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic): Surf clam. Report BS-82/11.13, *US Fish Wildlife Service*, Washington, DC.

Ginn BK, Logan A, Thomas MLH, Van Soest RWM (1998). Hymedesmia Canadensis (porifera:poecilosclerida), a new species among new geographical records from the Bay of Fundy, New Brunswick, Canada. *Journal of the Marine Biological Association of the United Kingdom* 78:1093-1100.

Gosner, KL (1979) A field guide to the Atlantic seashore. Houghton Mifflin Company, New York, NY.

Kidwell, SM (2002) Time-averaged molluscan death assemblages: Palimpsests of richness, snapshots of abundance. *Geology* 30(9):803-806.

Lubchenco J, Menge BA (1978) Community development and persistence in a low rocky intertidal zone. *Ecological Monographs* 59:67-94.

Metaxas A, Hunt H, Scheibling RE (1994) Spatial and temporal variability of macrobenthic communities in tidepools on a rocky shore in Nova Scotia. *Marine Ecology - Progress Series* 105(1-2):89-103.

Nautical Data International (2006) National digital ocean: Nova Scotia south – Bay of Fundy to Cape Cod, ATL3. Nautical Data International Inc, St. John's, Nfld.

Roland ER (1982) Geological background and physiography of Nova Scotia. Nova Scotia Institute of Science and Nova Scotia Museum, Halifax, NS.

Roman CT, Jaworski N, Short FT, Findlay S, Warren RS (2000) Estuaries of the northeastern United States: Habitat and land use signatures. *Estuaries* 23(6):743-764.

Sol D (2000) Are islands more susceptible to be invaded then continents? Birds say no. *Ecography* 23(6):687-692.

Tremblay JM (2002) Large epibenthic invertebrates in the Bras d'Or Lakes. *Proceedings of the Nova Scotian Institute of Science* 42(1):101-126.

Weiss HM (1995) Marine animals of southern New England and New York: Identification keys to common nearshore and shallow water macrofauna. State Geological and Natural History Survey of Connecticut, Harford, Connecticut.

Wentworth CK (1992) A scale of grade and class terms for clastic sediments. *Journal of Geology* 30(5):377-392.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 18-34

BEETLES (COLEOPTERA) OF SCATARIE ISLAND, NOVA SCOTIA, CANADA

CHRISTOPHER G. MAJKA[1]*, SHEENA M. TOWNSEND[2], KATHLEEN R. AIKENS[2], JEFFREY OGDEN[3], A. ANDREW M. MACDONALD[2] AND DAVID B. MCCORQUODALE[2]

[1] *Nova Scotia Museum*
1747 Summer Street
Halifax, Nova Scotia B3H 3A6

[2] *Department of Biology, Cape Breton University*
1250 Grand Lake Road
Sydney, Nova Scotia B1P 6L2

[3] *Nova Scotia Department of Natural Resources*
PO Box 130
Shubenacadie, Nova Scotia B0N 2H0

Beetles were collected as part of a biodiversity survey of Scatarie Island. Ninety-four species of Coleoptera have now been recorded from Scatarie Island, including 81 native and 13 introduced Palaearctic species. Seventeen species are recorded for the first time for Cape Breton Island. Of these five, *Atheta remulsa* Casey, *Baeocera youngi* (Cornell), *Cyphon confusus* Brown, *Scirtes tibialis* Guérin-Méneville, and *Trixagus carinicollis* (Schaeffer) are recorded for the first time in Nova Scotia. Other noteworthy records include the coccinellid *Hyperaspis brunnescens* (Dobzhansky), previously known from the American Midwest; an undescribed weevil in the genus *Parenthis,* and *Atheta (Datomicra) acadiensis* Klimaszewski & Majka, a recently described aleocharine rove beetle known only from the Maritime Provinces. The composition of this fauna is briefly discussed in the context of introduced species, flightless species, and island biogeography and biodiversity benchmarks in the province and region. Preliminary indications are that no more than (and possibly considerably less than) 2/3 of the predicted fauna on Scatarie Island has this far been documented. The composition of this island fauna is compared to the “source” fauna found in Cape Breton County to determine how representative the Scatarie Island fauna may be of the beetles found on the adjacent mainland.

Des coléoptères ont été prélevés dans le cadre d’une étude de la biodiversité de l’île Scatarie. À ce jour, 94 espèces de coléoptères ont été recensées dans l’île, dont 81 espèces indigènes et 13 espèces paléarctiques introduites. Dix-sept de ces espèces sont recensées pour la première fois dans l’île du Cap-Breton et cinq de ces dix-septespèces, soit *Atheta remulsa* Casey, *Baeocera youngi* (Cornell), *Cyphon confusus* Brown, *Scirtes tibialis*

---

* Author to whom correspondence should be addressed.
Email: cmajka@ns.sympatico.ca

Guérin-Méneville et *Trixagus carinicollis* (Schaeffer), sont recensées pour la première fois en Nouvelle-Écosse. Parmi les autres espèces observées, il y a lieu de signaler la coccinelle *Hyperaspis brunnescens* (Dobzhansky), qu'on savait présente dans le Midwest des États-Unis, une espèce non décrite de charançon du genre *Parenthis,* ainsi qu'*Atheta (Datomicra) acadiensis* Klimaszewski et Majka, une espèce de staphylin, de la sous-famille Aleocharin, qui vient d'être décrite et qui n'a été recensée à ce jour que dans les provinces Maritimes. On discute ici brièvement de la composition de cette faune dans le contexte des espèces introduites et des espèces aptères, et aussi de la biogéographie et des indices de référence en matière de biodiversité dans la province et dans la région. D'après les indications préliminaires, on aurait documenté jusqu'ici tout au plus les 2/3 (voire une proportion bien plus basse) de la faune qu'on pense trouver dans l'île Scatarie. Pour déterminer dans quelle mesure la faune de cette île est représentative des coléoptères présents dans la péninsule adjacente, on a comparé sa composition à celle de la faune « source » se trouvant dans le comté du Cap-Breton.

INTRODUCTION

Beetles (Coleoptera) are a hyper-diverse Order of insects found throughout the globe (except for the Antarctic) in every terrestrial and freshwater habitat, and with a small number of littoral and semi-marine species. Worldwide they are considered to be the most diverse living Order. Over 350,000 species have been described, some 25,160 of which have been recorded in North America (Marske & Ivie 2003). Danks (1978) estimated that 9,116 species are found in Canada, making them the third most species-rich Order in the country (after Hymenoptera, with 16,665 species and Diptera, with 14,481), constituting approximately 16.7% of the estimated 54,629 species of insects found in Canada. Consequently, understanding beetle faunas is an indispensable part of biodiversity studies. As hyper-diverse niche specialists, beetles are very useful in developing a "fine-grain" ecological understanding of the structure of environments. As such, and because they are readily collected at many times of the year, and their systematics and taxonomy are now comparatively well-understood in North America, beetles can be of great utility in environmental monitoring and in environmental impact studies.

Recent work has dramatically increased the number of species known from Atlantic Canada, by more than 35% in many families (e.g. McCorquodale & Bondrup-Nielsen 2004, Majka et al. 2007b), and newly described species change our view of geographic affinities (e.g. Klimaszewski et al. 2005, Klimaszewski & Majka 2007a, b). These recent efforts illustrate clearly that there is much more to learn, especially in those areas that have been underrepresented or comprise ecologically or geographically significant areas. Scatarie Island is one of these.

Thus the documentation of Scatarie Island's Coleoptera is an important, but previously neglected, goal and provides an opportunity to advance understanding of the relationship between mainland and island faunas in the region and to examine other questions related to island biogeography and geographic range.

SITE DESCRIPTION

Scatarie Island is a small (1,497 ha) island located approximately 2 km off the eastern shore of Cape Breton Island, Nova Scotia near Main-a-Dieu (Fig 1). The eastern shore of Cape Breton, including Scatarie Island, is in the Till Plain District of the Atlantic Coastal Theme Region (Davis & Browne 1997; analogous to Atlantic Coast Ecoregion of the Atlantic Maritime Ecozone [Ecological Stratification Working Group 1996] and Cape Breton Coastal Ecodistrict of the Acadian Forest Ecozone [Neily et al. 2003]). Cool ocean waters and salt spray result in vegetation with boreal characteristics; dense stands of black spruce, *Picea mariana* (Mill.) and balsam fir, *Abies*

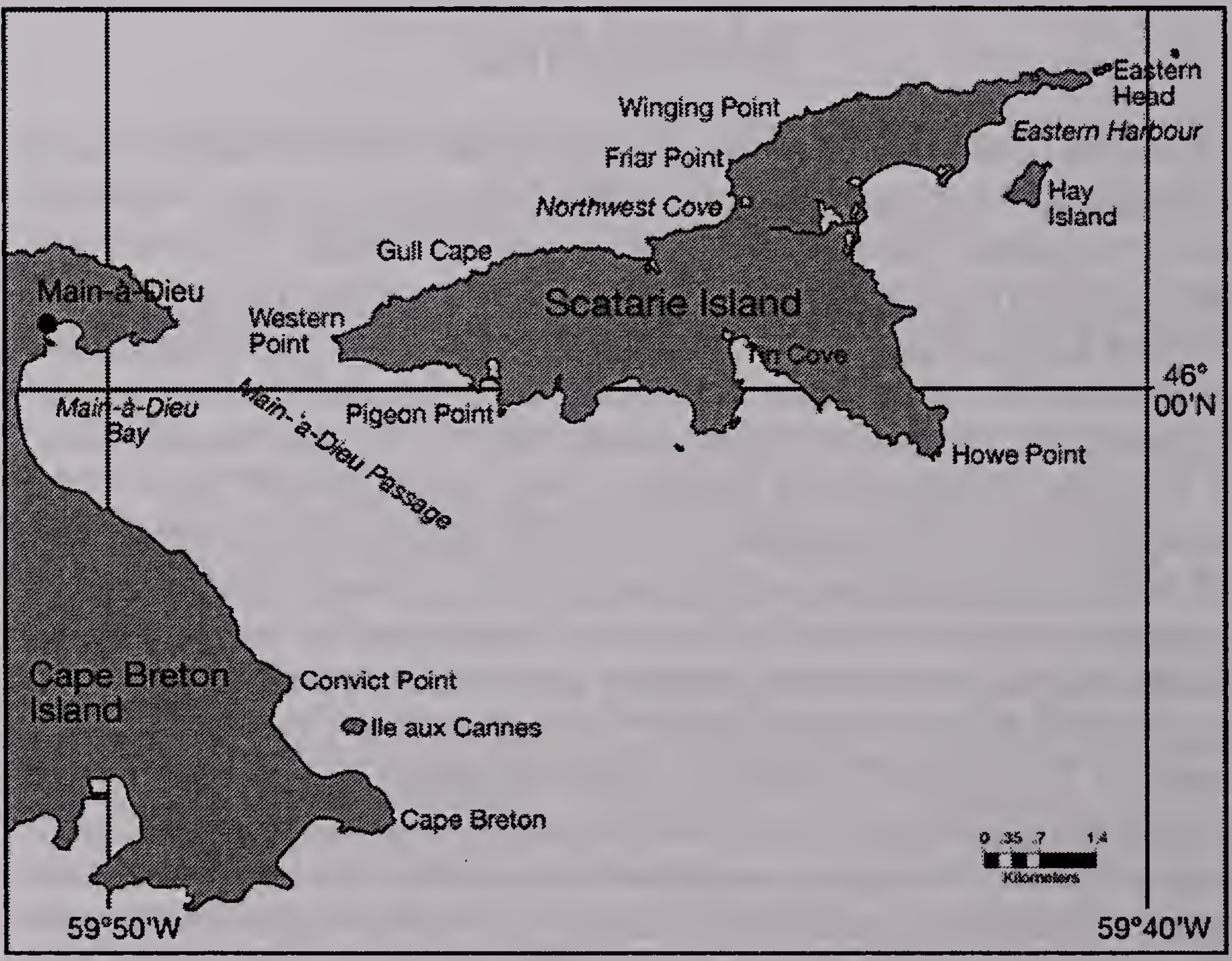


Fig 1 Scatarie Island

balsamea (L.) Mill dominate much of the island (Davis & Browne 1997). Poor drainage contributes to extensive peatlands and small ponds, including coastal barrachois. The headlands in the east are heath barrens characterized by *Empetrum nigrum* L., *Cornus canadensis* L. and *Vaccinium* spp. The shoreline is mostly rocky, with a few small sand and pebble beaches, often with abundant beach wrack and backshore zones of dune grasses, *Elymus mollis* Trin., *Ammophila brevigulata* Fern., and beach pea, *Lathyrus maritimus* (L.).

Although the island is now protected under Nova Scotia's Wilderness Protection Act, a number of dwellings remain on the eastern end of the island (Cameron 2004). European fishers have used the island since the 15th century, often only in the summer, but during the 19th and 20th centuries there were permanent residences, even communities on the island (Chrestien 2001). Where land was cleared, paper birch, *Betula papyrifera* Marshall, and white spruce, *Picea glauca* (Moench) Voss, are prominent.

Scatarie is small but comprises diverse habitats. A number of plants that are normally found in harsher and more northerly locations are present on the island. As such, Scatarie represents part of the southern edge of the range for these plants, which include *Cornus suecica* L., *Vaccinium uliginosum* L. (alpine whortleberry), *Prenanthes nana* (Bigel) Torr (Pronych & Wilson 1993) and *Carex rariflora* (Wahlenb.) J.E. Smith (Roland 1998).

COLLECTION METHODS

Beetles were collected on Scatarie Island, Nova Scotia between 8-11 August 2005 and between 14-17 July 2006. Habitats surveyed included coniferous forest, sandy shore, beach grass, open headland/barren, inland barren, and trailside. Insects were collected by sweep-netting (sweeping with an insect net), pitfall and bowl trapping, malaise trapping, dip-netting, and by hand from a variety of habitats.

Plastic beer cups (diameter nine cm) buried in the substrate up to the rim functioned as pitfall traps. A raised pieced of plywood above the trap protected contents from rainwater and debris. Five pitfall traps were deployed along a sandy beach in Northwest Cove, 8-11 August 2005. Three of these traps were along open beach, while two were in dune grass. Four pitfall and two bowl traps were also deployed along a trail running north-south from Northwest Cove to Tin Cove, 9-11 August 2005. A Townsend-style malaise trap, a tent-like structure which funnels flying insects into a collection chamber, was used to capture flying Coleoptera.

At Northwest Cove, dune grass, *Elymus mollis*, beach grass, *Ammophila brevigulata,* and rose, *Rosa* sp. were swept. Trailside vegetation was swept including alders (*Alnus viridis* (Villars) Lamb. and *A. incana* (L.) Moench), grasses, buttercups, and many Asteraceae (e.g. *Solidago* spp., *Aster* spp.). An inland barren southwest of Savage Cove, the headland above Tin Cove, and backshore vegetation at Savage Cove were swept. Beetles were hand collected from mushrooms (Basidiomycetes), a Leach's Storm-petrel, *Oceanodroma leucorhoa* (Vieillot) burrow, and beach wrack. Small rocks and sand underneath the wrack were sifted for beetles.

All specimens are now in the collections of Nova Scotia Department of Natural Resources, Shubenacadie, Nova Scotia Museum, Halifax, or Cape Breton University, Sydney, Nova Scotia.

RESULTS

Ninety-one species of Coleoptera (290 specimens in 26 families) were collected on Scatarie Island, Cape Breton County, Nova Scotia, 8-11 August 2005 and 14-17 July 2006 (Table 1), bringing the total species documented for the island to 94; 81 native species and 13 introduced species. Three species previously collected on Scatarie Island were not found during this collecting programme. Seventeen species are recorded for the first time from Cape Breton Island. Five of these, *Atheta remulsa* Casey, *Baeocera youngi* (Cornell), *Cyphon confusus* Brown, *Scirtes tibialis* Guérin-Méneville, and *Trixagus carinicollis* (Schaeffer) are recorded for the first time in Nova Scotia and one species, *Hyperaspis brunnescens* (Dobzhansky), was recorded for the first time in Canada (Majka et al. 2007a).

Table 1 Species of Coleoptera collected on Scatarie Island, Nova Scotia

Carabidae
Sphaeroderus c. canadensis Chaudoir – 1
Bembidion scopulinum (Kirby) – 2
† *Bembidion tetracolum* Say – 1
Bembidion transversale Dejean – 5
Pterostichus coracinus (Newman) – 3
† * *Amara communis* (Panzer) – 2
Pseudamara arenaria (LeConte) – 1
Harpalus fulvilabris Mannerheim – 1
Calathus ingratus Dejean – 1

Gyrinidae
Gyrinus affinis Aubé – 1
Gyrinus cavatus Atton – 5
Gyrinus sayi Aubé – 22

Haliplidae
Haliplus immaculicollis Harris – 1

Dytiscidae
Hydroporus signatus Mannerheim – 1
Hygrotus impressopunctatus (Schaller) – 3
Hygrotus sayi Balfour-Brown – 9
Neoporus undulatus (Say) – 20
Agabus inscriptus (Crotch) – 1
Ilybius angustior (Gyllenhal) – 1
Ilybius biguttulus (Germar) – 9
Rhantus wallisi Hatch – 3
Acilius semisulcatus Aubé – 1

Table 1 *Continued*

Hydrophilidae
Anacaena limbata (Fabricius) – 2
Hydrobius fuscipes (Linnaeus) – 1
Cercyon litoralis (Gyllenhal) – 13

Histeridae
Hypocaccus fraternus (Say) – 2

Staphylinidae
† *Tachyporus dispar* (Paykull) – 1
Lordithon scutellaris Campbell – 1
† * *Aleochara (Xenochara) fumata* Gravenhorst – 1
Aleochara (Emplenota) litoralis (Mäklin) – 2
† * *Gyrophaena affinis* Mannerheim – 1
** *Atheta remulsa* Casey – 3
* *Atheta (Datomicra) acadiensis* Klimaszewski & Majka – 8
Atheta (Microdota) pennsylvanica Bernhauer – 1
** *Baeocera youngi* (Cornell) – 1
Creophilus maxillosus villosus (Gravenhorst) – 1
† *Tasgius ater* (Gravenhorst) – 2
Gabrius picipennis (Mäklin) – 5
† *Philonthus politus* (Linnaeus) – 2

Anthicidae
Anthicus scabriceps LeConte – 3

Scarabaeidae
* *Aegialia lacustris* LeConte – 1
† *Calamosternus granarius* (Linnaeus) – 1
Diplotaxis tristis Kirby – 1

Scirtidae
** *Cyphon confusus* Brown – 1
Cyphon variabilis Thunberg – 13
** *Scirtes tibialis* Guérin-Méneville – 1

Buprestidae
Agrilus pensus Horn – 1

Throscidae
** *Trixagus carinicollis* (Schaeffer) – 1

Elateridae
Agriotes fucosus (LeConte) – 1
Agriotes limosus (LeConte) – 1
Dalopius vagus Brown – 8
Athous rufifrons (Randall) – 1
Liotrichus falsificia (LeConte) – 1
Pseudanostirus triundulatus (Randall) – 1
* *Negastrius delumbis* (Horn) – 2

Lycidae
Plateros lictor (Newman) – 1

Cantharidae
Rhagonycha m. mollis Fall – 1
Rhagonycha nanula (LeConte) – 8
Rhagonycha scitula (Say) – 11
Malthodes species – 1

Trogossitidae
* *Thymalus marginicollis* Chevrolat – 1

Phalacridae
Olibrus semistriatus LeConte – 2

Cryptophagidae
* *Atomaria* fuscata Schönherr– 3
* *Atomaria testacea* Stephens – 1

Coccinellidae
*** *Hyperaspis brunnescens* (Dobzhansky) – 1
Anisosticta bitriangularis (Say) – 1

Lathridiidae
Corticarina cavicollis (Mannerheim) – 4

Tenebrionidae
Isomira quadristriata (Couper) – 1

Scraptidae
Anaspis rufa Say – 9

Cerambycidae
Lepturobosca chrysocoma (Kirby) – 1
Xylotrechus undulatus (Say) – 2
Monochamus s. scutellatus (Say) – 1

Table 1 *Continued*

Chrysomelidae
Plateumaris nitida (Germar) – 1
Plateumaris pusilla (Say) – 8
* *Donacia rugosa* LeConte – 4
Trirhabda virgata LeConte – 10
Trirhabda borealis Blake – 5
Tricholochmaea kalmiae (Fall) – 3
Neogalerucella quebecensis Brown – 9
Dibolia borealis Chevrolat – 1
Syneta ferruginea (Germar) – 1

Attelabidae
* *Himatolabus pubescens* (Say) – 2

Curculionidae
* *Anthonomus corvulus* LeConte – 1
Pseudanthonomus validus Dietz – 1
Orchestes pallicornis (Say) – 5
Ceutorhynchus hamiltoni Dietz – 2
Parenthis species (undescribed) – 4
† *Rhinoncus castor* (Fabricius) – 1
† *Strophosoma melanogrammum* (Forster) –1
† *Barynotus schoenherri* Zetterstedt – 1
† *Otiorhynchus ligneus* (Olivier) – 1
† *Otiorhynchus ovatus* (Linnaeus) – 2
Sitona lineellus (Bonsdorff) – 2
Polygraphus rufipennis (Kirby) – 1

Notes:
*, species newly recorded on Cape Breton Island
**, species newly recorded in Nova Scotia
***, species newly recorded in Canada
†, introduced species
The numerals listed after each species indicate numbers of specimens collected.

Specific Notes: Native Species

Atheta remulsa Casey was recently reported for the first time in eastern North America from specimens collected in New Brunswick (Klimaszewski et al. 2005). It is herein recorded for the first time in Nova Scotia. In New Brunswick it was collected in pitfall traps in a mixed coniferous-deciduous forest. Beyond this, nothing is known of its bionomics.

Atheta (Datomicra) acadiensis Klimaszewski & Majka was recently described from specimens collected from beach-drift material on oceanic beaches in New Brunswick, Prince Edward Island, and Nova Scotia (Klimaszewski & Majka 2007a).

Baeocera youngi (Cornell) is one of the shining fungus beetles (Scaphidinae), a group that feed on slime molds and sporophores of basidiomycete fungi (Löbl & Stephan 1993). It is herein recorded for the first time in Nova Scotia.

Aegialia lacustris is recorded for only the third time in Nova Scotia. Previous records are from Guysborough and Digby counties (Majka 2009). Species in this genus are detritivores associated with sandy, riparian, or littoral habitats (Ratcliffe et al. 2002).

Cyphon confusus Brown: the genus *Cyphon* in the Maritime Provinces is currently under revision by Majka and Klausnitzer. The present species determination may change. Scirtid larvae are aquatic and semi aquatic; adults are found in marshy environments (Young 2002).

Cyphon variabilis Thunberg: the genus *Cyphon* in the Maritime Provinces is currently under revision by Majka and Klausnitzer. The present species determination may change.

Scirtes tibialis Guérin-Méneville is herein recorded for the first time in Nova Scotia.

Trixagus carinicollis (Schaeffer) is herein recorded for the first time in Nova Scotia. The species is actually very widespread and abundant throughout the province (Majka 2009). Throscids are generalist pollen and mould feeders (Johnson 2002).

Agriotes fucosus (LeConte) is a rather uncommon click beetle in Nova Scotia, primarily recorded from coastal areas (Sable Island, St. Paul Island, and Scatarie Island) of the province.

Negastrius delumbis (Horn) is an uncommon click beetle with a scattered distribution in the province. Beetles in this genus are frequently found at the edge of water under sticks or stones, or are beaten from foliage in damp places (Downie & Arnett 1996).

Malthodes sp: the specimen collected on Scatarie Island is a female of either *M. fragilis* (LeConte), *M. fuliginosus fuliginosus* LeConte, or *M. similis* Fender. All three species have been collected in Cape Breton County. Females in this genus can only be identified in association with males.

Hyperaspis brunnescens (Dobzhansky) (Fig. 7) was recorded for the first time in Canada and eastern North America by Majka et al. (2007a) from this collection on Scatarie Island. The specimen was found in the mouth of a Leach's Petrel burrow. It was previously known only from the mid-western United States (Gordon 1985). Consequently this discovery represents a range extension of some 2,100 kilometers. It is one of the rarest of North American lady beetles with only 19 specimens having been previously collected. Species of *Hyperaspis* are predaceous or parasitic on various species of Homoptera.

Donacia rugosa LeConte has only been previously recorded in southern Nova Scotia (Majka 2009). Species in this genus are always associated with emergent vegetation in, or adjacent to, fresh water, usually *Pontederia cordata* L. (Pontedariaceae) (Clark et al. 2004). This host plant has not been recorded from Scatarie Island.

Himatolabus pubescens (Say) is a leaf-roller associated with oaks, *Quercus* spp., alders, *Alnus* spp., or beaked hazel, *Corylus cornuta* Marshall. This beetle has previously been reported from Guysborough, Halifax and Queens counties but not on Cape Breton Island (Majka et al. 2007b). Of the known hosts, only alders, *Alnus crispa* and *A. incana,* are present on Scatarie Island.

Parenthis species: this is a undescribed species in the Ceutorhynchinae. Specimens have been recently recognized in collections from Ontario, Québec, New Brunswick, and Nova Scotia. It is associated with *Potentilla palustris* (L.) Scop., a cinquefoil found on muddy shores, swamps, and edges of ponds including on Scatarie Island (Majka 2009).

Specific Notes: Introduced Species

Bembidion tetracolum Say was introduced to North America and first reported from Nova Scotia in 1954, and the west coast of Canada in 1949 (Lindroth 1963). It is found in a variety of habitats, including riverbanks, cultivated fields, pastures, gardens, wharves, and sand pits, and is often associated with human habitation (Larochelle & Larivière 2003).

Amara communis (Panzer) was first reported in North America from specimens collected in New Brunswick in 1988 (Bousquet 1992). Majka (2005) subsequently reported it from a number of localities along the Bay of Fundy in Nova Scotia and from Prince Edward Island. He proposed that the coastal distribution of the species, and its association with localities which had a history of shipping and marine traffic, indicated that it had been introduced in conjunction with dry-ballast shipping. The discovery of this species on Scatarie Island supports this contention. It is herein newly recorded on Cape Breton Island.

Tachyporus dispar (Paykull) is an introduced Palaearctic rove beetle first found in North America in Washington in 1928 (Hatch 1953) and in Nova Scotia in 1951 (Majka & Klimaszewski 2008). It is frequently found in decaying leaf litter, in compost, under moss, and in river debris (Campbell 1979).

Aleochara (Xenochara) fumata Gravenhorst is an introduced Palaearctic rove beetle known in North America since at least 1906 (Klimaszewski 1984) and in Nova Scotia since 1910 (Majka & Klimaszewski 2008). It is widely distributed in Canada and the United States. Adults and larvae are active predators of cyclorrhaphous Diptera and are found in decaying mushrooms and various organic debris (Klimaszewski 1984).

Gyrophaena affinis Mannerheim is an introduced Palaearctic rove beetle known in North America since at least 1906 (Seevers 1951). It is widely distributed in Canada and the United States and is one of the most abundant species in this genus. Species of *Gyrophaena* are mycetophagous and inhabit fleshy fungi (Seevers 1951)

Tasgius ater (Gravenhorst) was first recorded in North America in 1802 and in Nova Scotia in 1938 (Newton 1987). It is found under debris near water including marine situations but is also common inland in synanthropic situations including urban areas (Newton et al. 2000).

Philonthus politus (Linnaeus) was also recorded by Kirby (1837) in Nova Scotia where it is now widely distributed (Smetana 1995). It is predaceous on fly larvae in environments where decay occurs, including synanthropic situations (Smetana 1995). Recently Majka *et al.* (2006) recorded this rove beetle from a Boreal Owl (*Aegolius funereus richardsoni* (Bonaparte)) nest in northern Cape Breton.

Calamosternus granarius (Linnaeus) is an introduced, Palaearctic scarab beetle that occurs throughout Canada (Campbell et al. 1989). Although there are records in Nova Scotia as early as 1914, it was not noted by Brown (1940, 1950, 1967) or Lindroth (1957) in their reviews of introduced species in Atlantic Canada. It is commonly collected in cow dung and also feeds on the roots of grasses. On Scatarie Island it was found under beach wrack.

Rhinoncus castor (Fabricius) was first recorded in North America in New Jersey in 1895 (Brown 1950) and in Nova Scotia in 1946 (Majka et al. 2007b). It is widely distributed in Nova Scotia and associated with *Rumex acetosella* L., *Medicago sativa* L., and *Oenanthe* spp. (Hoebeke & Whitehead 1980).

Barynotus schoenherri (Zetterstedt) was first recorded in North America in 1876 in Newfoundland (Brown 1950) and in Nova Scotia in 1884 (Harrington 1891). In Nova Scotia it is primarily found on Cape Breton and in Annapolis County (Majka et al. 2007b). Adults of this flightless, terricolous species feed on foliage (Anderson 2002).

Strophosoma melanogrammum (Forster) was first recorded in North America in New Jersey in 1885. It was first recorded in Nova Scotia in 1924 and by 1940 it had been found on Cape Breton (Brown 1940, Majka et al. 2007b). It is a flightless, terricolous species.

Otiorhynchus ligneus (Olivier) was first recorded in North America in New Brunswick in 1917 and in Nova Scotia in 1927 (Majka et al. 2007b). It is a flightless, terricolous species. In Europe it associated with plants such as *Diplotaxis tenuifolia* (L.) DC. (Brassicaceae), *Reseda luteola* L. (Resedaceae), and *Scorzonera humilis* L. (Asteraceae) (Majka et al. 2007b).

Otiorhynchus ovatus (Linnaeus) was first recorded in Nova Scotia in 1884 (Majka et al. 2007b). This is a very widespread weevil in North America as a whole, and also within Cape Breton. It is a common pest of agricultural crops. The larvae feed on roots (Campbell et al. 1989).

DISCUSSION

The presence of *Sphaeroderus c. canadensis* and *Pterostichus coracinus,* are noteworthy since both native species are brachypterous and incapable of flight (Larochelle & Larivière 2003), raising interesting questions as to how these species would have colonized Scatarie Island. The introduced weevils, *Barynotus schoenherri, Otiorhynchus ligneus, Otiorhynchus ovatus,* and *Strophosoma melanogrammum* are also brachypterous, an indication that they were introduced to the island in association with past human activities. Other species of beetles recorded to date on Scatarie Island are (insofar as is known) macropterous and capable of flight.

Thirteen of 94 species (14 %) of beetles found to date on the island are introduced species, similar to the 15.5 % of introduced beetles found in Nova Scotia (Majka 2009). Although Scatarie Island is currently uninhabited, the substantial fraction of introduced species found there is reflective of its history of habitation.

What is the potential scale of the Scatarie Island beetle fauna? The 94 species recorded from Scatarie Island are clearly not a complete inventory of the species present on the island. Knowledge of Atlantic Canada beetle fauna in general, and island beetle faunas in particular, is incomplete, consequently there are few studies that would provide a comparison. In a study of the beetle fauna of Brier Island (one km from the mainland and ~ 1,450 ha in size) Ogden and Majka (2009) have found 150 species of Coleoptera. On Sable Island (160 km from the mainland and ~ 3,400 ha in area) Wright (1989) recorded 144 species of beetles. Larson et al. (1999) conducted a study on Brunette Island, 15 km from the south coast of Newfoundland and approximately 2,000 ha in size. Focusing solely on ground (Carabidae) and water (Haliplidae, Dytiscidae, Gyrinidae, Hydrophilidae, Elmidae, and one species of Chrysomelidae) beetles, the authors collected 70 species in these families over a similar collecting period (9 days over two collecting seasons on Brunette Island; 8 days over two collecting seasons on Scatarie Island). This compares to 27 species in this same grouping of families on Scatarie Island. Brunette Island is similar in size to Scatarie Island, has similar range of habitats, and a similar history of past human habitation. It is further from the "mainland" which would suggest that more species might have been able to successfully colonize Scatarie owing to a greater proximity of source populations.

In general, island faunas (in comparison with those of the neighbouring "source" populations, i.e., the mainland) are inversely proportional to the distance from the mainland and directly proportional to the size of the island (McArthur & Wilson 1967). For Scatarie the "mainland" source fauna is Cape Breton County where 603 species of beetles have been recorded so far (Majka 2009). On Brunette Island Larson et al. (1999) found that the species collected on the island represented 24% of the fauna of these families occurring on the "mainland" of the island of Newfoundland. If one takes the 603 species found in Cape Breton County as a minimum "source" population for the colonization of Scatarie Island, and assumes 24% as a minimum insular ratio for an island of the size of Scatarie, this would indicate ~145 species as the approximate scale of the Scatarie Island beetle fauna. While both preliminary and speculative, this projection produces species numbers very similar to those recorded for Brier Island and Sable Island.

How representative is the known Scatarie Island fauna of the "source" mainland fauna? Fig 2 illustrates the proportional composition of both the Scatarie Island beetle fauna, and the beetle fauna of Cape Breton County overall. In the case of the Buprestidae, Cerambycidae, Chrysomelidae, Cryptophagidae, Curculionidae, Histeridae, Hydrophilidae, Staphylinidae, and Tenebrionidae, there was a very close proportional correspondence between the two. In the case of the Carabidae and Coccinellidae, the proportional representation on Scatarie Island was markedly less than on the "mainland." These differences could reflect differential abilities of members of these families of beetles to disperse to and colonize island habitats, a lack of suitable habitats, a deficit in collecting

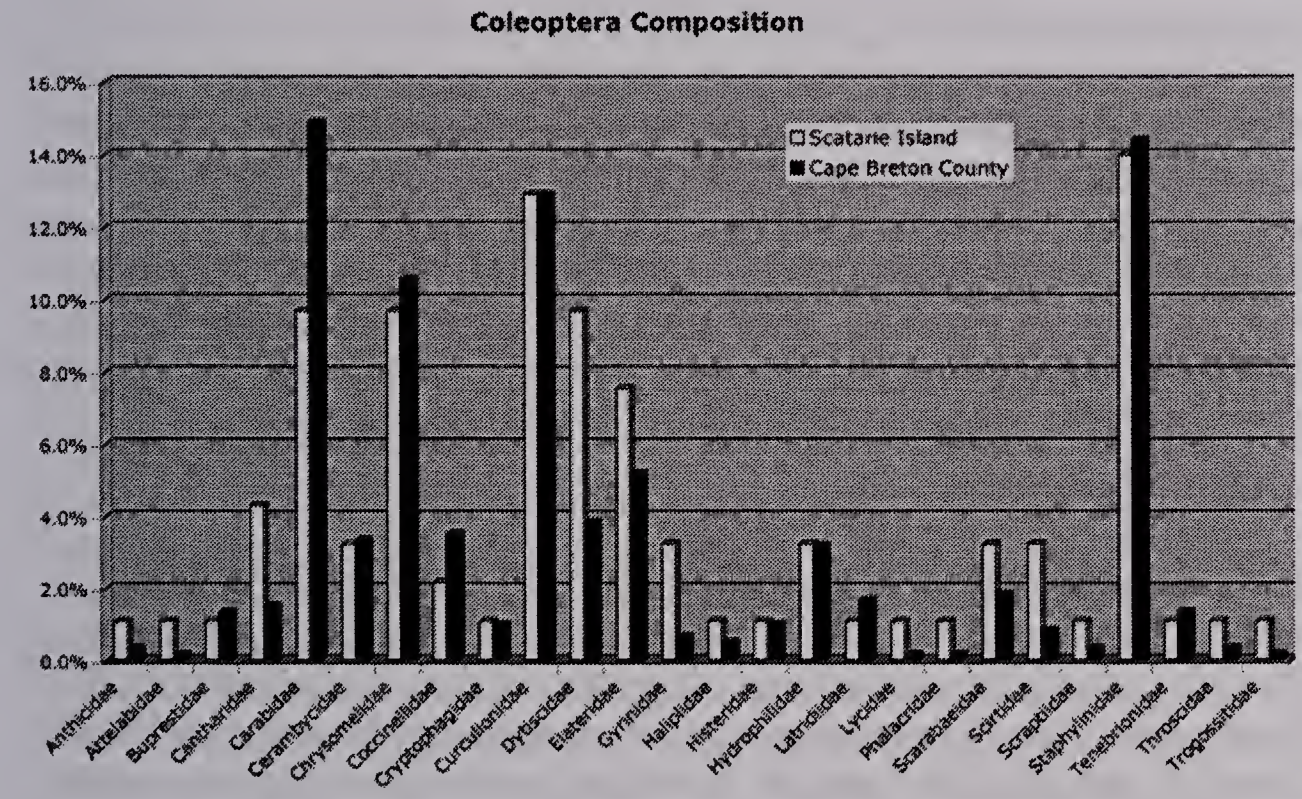


Fig 2 The proportional composition of Coleoptera on Scatarie Island and of Cape Breton County.

effort that has underrepresented some species found on Scatarie Island, or a combination of these factors.

In the case of Cantharidae, Elateridae, Dytiscidae, Gyrinidae, and Scirtidae the proportional representation on Scatarie Island is greater than on the adjacent "mainland." This may in part reflect the suite of available habitats on Scatarie Island for forest species such as the Cantharidae and Elateridae, aquatic species such as the Dytiscidae and Gyrinidae, and marsh/swamp specialists such as the Scirtidae. It could also be a collecting artifact: as more species of beetles of other families are found on Scatarie Island, the proportional representation of these families in the composition of the fauna may decrease. Only further research and collecting on Scatarie Island can help to resolve questions such as these and allow us to derive a fuller understanding of the fauna of the island, and consequently of its history and development.

In order to shed some light on invertebrate biodiversity, it is important to develop comprehensive faunal inventories for at least a few representative sites in a region. Such inventories can be used as benchmarks in studies of ecology, zoogeography, climate change, and the impact of invasive species. Islands, because of their distinct boundaries, offer excellent opportunities for studies which can shed light not only on the processes of island biodiversity, colonization, extirpation, but which can also serve as comparative biodiversity benchmarks.

Acknowledgments. We extend thanks to Robert Anderson (Canadian Museum of Nature), Patrice Bouchard, Yves Bousquet, and Laurent LeSage (Agriculture and Agri-food Canada), Robert Gordon (Northern Plains Entomology) Jan Klimaszewski (Canadian Forest Service), and David Larson for assistance with determinations. CGM would like to thank his colleagues, David Christianson, Calum Ewing, and Andrew Hebda, for continuing support and encouragement. Financial support was provided by CBU research grants to DBM. We all thank Rob Cameron, NS Department of Environment and Labour for organizing the trip and all the other participants for assistance on the August 2005 trip to Scatarie Island.

Notes. Information on the composition of the Cape Breton County Coleoptera fauna is derived from information supplied by C.G. Majka (2009).

REFERENCES

Anderson RS (2002) Curculionidae Latreille 1802. In: Arnett RH, Jr, Thomas MC, Skelley PE, Frank JH (eds) American Beetles, Vol 2: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, FL, p 722-815.

Bousquet Y (1992) *Bembidion femoratum* Sturm and *Amara communis* (Panzer) (Coleoptera: Carabidae) new to North America. *Journal of the New York Entomological Society* 100(3):503-509.

Brown WJ (1940) Notes on the American distribution of some species of Coleoptera common to the European and North American continents. *Canadian Entomologist* 72:65-78.

Brown WJ (1950) The extralimital distribution of some species of Coleoptera. *Canadian Entomologist* 82(10):197-205.

Brown WJ (1967) Notes on the extralimital distribution of some species of Coleoptera. *Canadian Entomologist* 99 (1):85-93.

Cameron RP (2004) Resources guide and ecological atlas for conducting research in Nova Scotia's wilderness areas and nature reserves. Technical Report 0401, Protected Areas Branch, Nova Scotia Environment and Labour, Halifax, NS.

Campbell JM (1979) A revision of the genus *Tachyporus* Gravenhorst (Coleoptera: Staphylinidae) of North and Central America. *Memoirs of the Entomological Society of Canada* 109.

Campbell JM, Sarazin MJ, Lyons DB (1989) Canadian beetles (Coleoptera) injurious to crops, ornamentals, stored products, and buildings. Agriculture Canada, Ottawa, ON.

Chrestien J-P (2001) Archaeological survey and testing of eighteenth-century fishing properties on Scatarie Island (Nova Scotia). Report for the year 2000, Canadian Museum of Civilization, Ottawa, ON.

Clark SM, LeDoux DG, Seeno TN, Riley EG, Gilbert AJ, Sullivan JM (2004) Host plants of leaf beetle species occurring in the United States and Canada (Coleoptera: Megalopodidae, Orsodacnidae and Chrysomelidae, excluding Bruchinae). Coleopterists Society Special Publication 2, Sacramento, CA.

Danks HV (1978) Canada and its insect fauna. *Memoirs of the Entomological Society of Canada* 108.

Davis DS, Browne S (1997) Natural History of Nova Scotia. Vol 2: Theme Regions. Nimbus Publishing and Nova Scotia Museum, Halifax, NS. [Available from: http://museum.gov.ns.ca/mnh/nature/nhns2/index.htm].

Downie NM, Arnett RH, Jr (1996) The beetles of northeastern North America. Sandhill Crane Press, Gainesville, FL.

Ecological Stratification Working Group (1996) A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull.

Gordon RD (1985) The Coccinellidae (Coleoptera) of America north of Mexico. *Journal of the New York Entomological Society* 93 (1):1-912.

Harrington WH (1891) Notes on a few Canadian Rhyncophora. *Canadian Entomologist* 23:21-27, 114.

Hatch MH (1953) The beetles of the Pacific Northwest, Part I: Introduction and Adephaga. University of Washington Press, Seattle, WA.

Hoebeke ER, Whitehead DR (1980) New records of *Rhinoncus bruchoides* (Herbst) for the Western Hemisphere and a revised key to the North American species of the genus *Rhinoncus* (Coleoptera: Curculionidae: Ceutorhynchinae). *Proceedings of the Entomological Society of Washington* 82:556-561.

Johnson PJ (2002) Throscidae Laporte 1840. In: Arnett RH, Jr, Thomas MC, Skelley PE, Frank, JH (eds) American Beetles, Volume 2: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, FL, p. 158-159.

Kirby W (1837) Fauna boreali-Americana or the Zoology of the northern parts of British America, containing descriptions of the objects of natural history collected on the late northern land expeditions, under the command of Captain Sir John Franklin, RN, by John Richardson. Volume 4. Norwich, England.

Klimaszewski J (1984) A revision of the genus *Aleochara* Gravenhorst of America north of Mexico (Coleoptera: Staphylinidae, Aleocharinae). *Memoirs of the Entomological Society of Canada* 129.

Klimaszewski J, Majka CG (2007a) Two new *Atheta* species from eastern Canada (Coleoptera, Staphylinidae, Aleocharinae): taxonomy, bionomics and distribution. *Canadian Entomologist* 139(1):45-53.

Klimaszewski J, Majka CG (2007b) *Euvira micmac*, a new species (Coleoptera, Staphylinidae, Aleocharinae), and first record of the genus in Canada. *Canadian Entomologist* 139(2):147-153.

Klimaszewski J, Sweeney J, Price J, Pelletier G (2005) Rove beetles (Coleoptera: Staphylinidae) in red spruce stands, eastern Canada: diversity, abundance, and descriptions of new species. *Canadian Entomologist* 137(1):1-48.

Larochelle A, Larivière M-C (2003) A natural history of the ground-beetles (Coleoptera: Carabidae) of America north of Mexico. Pensoft, Sofia, Bulgaria.

Larson D, Larson M, Fancy D, Raske A (1999) Ground and water beetles of Brunette Island, Newfoundland (Insecta: Coleoptera). *Northeastern Naturalist* 6(3):199-210.

Lindroth CH (1957) The faunal connections between Europe and North America. Almqvist and Wiksell, Stockholm.

Lindroth CH (1963) The ground beetles (Carabidae, excluding Cicindelinae) of Canada and Alaska. Part 3 Opuscula Entomologica Supplement 24, Lund, Sweden.

Löbl I, Stephan K (1993) A review of the species of *Baeocera* Erichson (Coleoptera, Staphylinidae, Scaphidinae) of America north of Mexico. *Revue Suisse de Zoologie* 100(3):675-733.

Majka CG (2005) The Palearctic species *Bembidion femoratum* and *Amara communis* (Coleoptera: Carabidae): new records and notes on modes of introduction to North America. *Canadian Entomologist* 137(5):532-538.

Majka CG (2009) (Nova Scotia Museum of Natural History, Halifax) Unpublished data.

Majka CG, Aikens KR, MacDonald A, Townsend SM, McCorquodale DB (2007a) *Hyperaspis brunnescens* Dobzhansky (Coleoptera: Coccinellidae) newly recorded in Canada from Scatarie Island, Nova Scotia. *Entomological News* 118(4):402-406.

Majka CG, Anderson RS, McCorquodale DB (2007b) The weevils of the Maritime Provinces of Canada, II: New records from Nova Scotia and Prince Edward Island and regional zoogeography (Coleoptera: Curculionoidea). *Canadian Entomologist* 139(3):397-442.

Majka CG, Klimaszewski J (2008) Introduced Staphylinidae (Coleoptera) in the Maritime Provinces of Canada. *Canadian Entomologist* 140(1):48-72.

Majka CG, Klimaszewski J, Lauff RF (2006) New Coleoptera records from owl nests in Nova Scotia, Canada. *Zootaxa* 1194:33-47.

Marske KA, Ivie MA (2003) Beetle fauna of the United States and Canada. *Coleopterists Bulletin* 57:495-503.

McArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton, NJ.

McCorquodale DB, Bondrup-Nielsen S (2004) Do we know beetles? Lessons from new records of Cerambycidae (Coleoptera) for Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 42(2):209-223.

Neily PD, Quigley E, Benjamin L, Stewart B, Duke T (2003) Ecological land classification for Nova Scotia Vol 1: Mapping Nova Scotia's terrestrial ecosystems. Report 2003-2, Nova Scotia Department of Natural Resources, Halifax, NS.

Newton AF, Jr (1987) Four *Staphylinus* (*sensu lato*) species new to North America, with notes on other introduced species (Coleoptera: Staphylinidae). *Coleopterists Bulletin* 41:381-384.

Newton AF, Thayer MK, Ashe JS, Chandler DS (2000) Staphylinidae Latreille, 1802. In: Arnett RH, Jr, Thomas MC (eds) American Beetles, Vol 1: Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia. CRC Press, Boca Raton, FL, p. 272-418.

Ogden J, Majka CJ (2009) (NS Dept Natural Resources, Shubenacadie and NS Museum of Natural History, Halifax) Unpublished data.

Pronych G, Wilson A (1993) Atlas of rare vascular plants in Nova Scotia. Vol 1 & 2. Curatorial Report 78, Nova Scotia Museum of Natural History, Halifax, NS.

Ratcliffe B, Jameson ML, Smith ABT (2002) Scarabaeidae Latreille 1802. In: Arnett RH, Jr, Thomas MC, Skelley PE, Frank JH (eds) American Beetles, Vol 2: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, FL, p. 39-81.

Roland AE (1998) Roland's Flora of Nova Scotia. Nimbus Publishing and the Nova Scotia Museum, Halifax, NS.

Seevers CH (1951) A revision of the North American and European staphylinid beetles of the subtribe Gyrophaenae (Aleocharinae: Bolitocharini). *Fieldiana Zoology* 32:655-762.

Smetana A (1995) Rove beetles of the subtribe Philonthina of America north of Mexico (Coleoptera: Staphylinidae) classification, phylogeny and taxonomic revision. Associated Publishers, Gainesville, FL.

Wright B (1989) The fauna of Sable Island, Nova Scotia. Curatorial Report 68, Nova Scotia Museum, Halifax, NS.

Young DK (2002) Scirtidae Fleming 1821. In: Arnett RH, Jr, Thomas MC, Skelley PE, Frank JH (eds) American Beetles, Volume 2: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, FL, p. 87-89.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 35-44

FRESHWATER AND INTERTIDAL FISHES OF SCATARIE ISLAND, NOVA SCOTIA

S. C. MITCHELL*
Department of Biology
St. Francis Xavier University
Antigonish, Nova Scotia B2G 2W5

Intertidal and shallow subtidal marine fish communities are largely undocumented in Atlantic Canada, as is the freshwater fish distribution on islands in this area. Accordingly Scatarie Island, off of the northeast coast of Cape Breton, was subjected to an intensive, short-term biological survey in the summer of 2005, in which freshwater and shallow water marine fish were sampled. The most commonly captured species were Atlantic herring (*Clupea harengus*), grubby (*Myoxocephalus aenaeus*), white hake (*Urophycis tenuis*) and cunner (*Tautogolabrus adspersus*). The catch per unit effort (CPUE) was low (<0.11 fish/hr) throughout all trapping sessions.

Les populations de poissons des zones intertidales et des zones infralittorales peu profondes sont peu documentées au Canada atlantique. Il en est de même de la répartition des poissons d'eau douce dans les îles de la région. C'est pourquoi l'île Scatarie, située au large de la côte nord-est du Cap-Breton, a fait l'objet d'une étude biologique intensive sur une courte période au cours de l'été 2005, dans laquelle des échantillons de poissons d'eau douce et de poissons d'eau de mer peu profonde ont été recueillis. Les espèces les plus capturées étaient le hareng de l'Atlantique (*Clupea harengus*), le chaboisseau bronzé (*Myoxocephalus aenaeus*), la merluche blanche (*Urophycis tenuis*) et la tanche-tautogue (*Tautogolabrus adspersus*). Les prises par unité d'effort (PUE) ont été faibles (< 0,11 poisson par heure) durant toutes les opérations de capture.

INTRODUCTION

Insular freshwater fish faunas are depauperate relative to neighboring mainland areas, requiring those species which do colonize and utilize freshwaters of islands to be tolerant of sea-water to effect a crossing. Basic island biogeography theory (MacArthur & Wilson 1967) predicts small islands with relatively little freshwater will be expected to have very few freshwater fish species, not only because of difficulties in colonization, but also because the risk of extinction occurring in small isolated populations is high. The freshwater fish fauna of Nova Scotia, the source population for nearby islands, is relatively low in terms of species richness compared with the adjacent provinces of New Brunswick and Québec, being approximately 35, 46 and 96, respectively (compiled from Scott and Crossman (1973)

---

*Email: smitchel@stfx.ca

and includes diadromous as well as wholly freshwater species). This low richness is a result of the river systems of Nova Scotia generally being short and isolated from each other, requiring colonization from river-to-river by sea-water tolerant species, or historic (post-glacial) colonization while the drainages were connected prior to isostatic rebound which separated catchments. The result is that the pool of available freshwater fish species to colonize offshore islands from the Nova Scotia mainland or Cape Breton is small to begin with. For these reasons offshore islands of Nova Scotia are expected to have low freshwater fish species richness, and those species present will be sea-water tolerant.

The intertidal and shallow subtidal fish fauna of rocky shores in Atlantic Canada is largely undocumented. Tyler (1971) reported use of intertidal areas by fish in Passamoquoddy Bay, New Brunswick. Black and Miller (1991) looked at use of intertidal areas by fish at six adjacent sites in Yarmouth County, Nova Scotia, and Stokesbury and Stokesbury (1999) examined shallow subtidal fishes in the Baie des Chaleurs. There is an absence of other published literature on the fish communities of these habitats in this area of the northwest Atlantic. The fish communities that do exist in the Maritimes may be expected to be of relatively low richness because of the annual disturbances (ice scour) of these environments; these frequent disturbances prevent establishment of high species richness over long time periods.

To date very little information has been collected on the freshwater or marine fish fauna associated with Scatarie Island. This knowledge is important for planning conservation or protection strategies and therefore, the fish fauna of the island's intertidal and freshwaters were sampled in August, 2005 as one component of a biological survey intended to provide the Protected Areas Branch with information for successfully managing this Wilderness Area.

STUDY AREA

Scatarie Island is washed by the Nova Scotia Current flowing out of Cabot Strait and traveling at an estimated 0.05-0.10 m/s (Davis & Browne, 1996). The coastal morphology of the shoreline is one of broad coves and indentations containing sand and cobble beaches interspersed with rocky headlands. SCUBA diving transects by Moore et al. (1986) at two locations (northern Scatarie and Tin Cove; see Figure 1) indicated a gentle sloping substrate of about 6% out for 120 to 160 m from shore (7 and 10 m depth by these points, respectively). These transects showed the substrate to be largely bedrock and boulders, with sand and scattered gravel. Algal

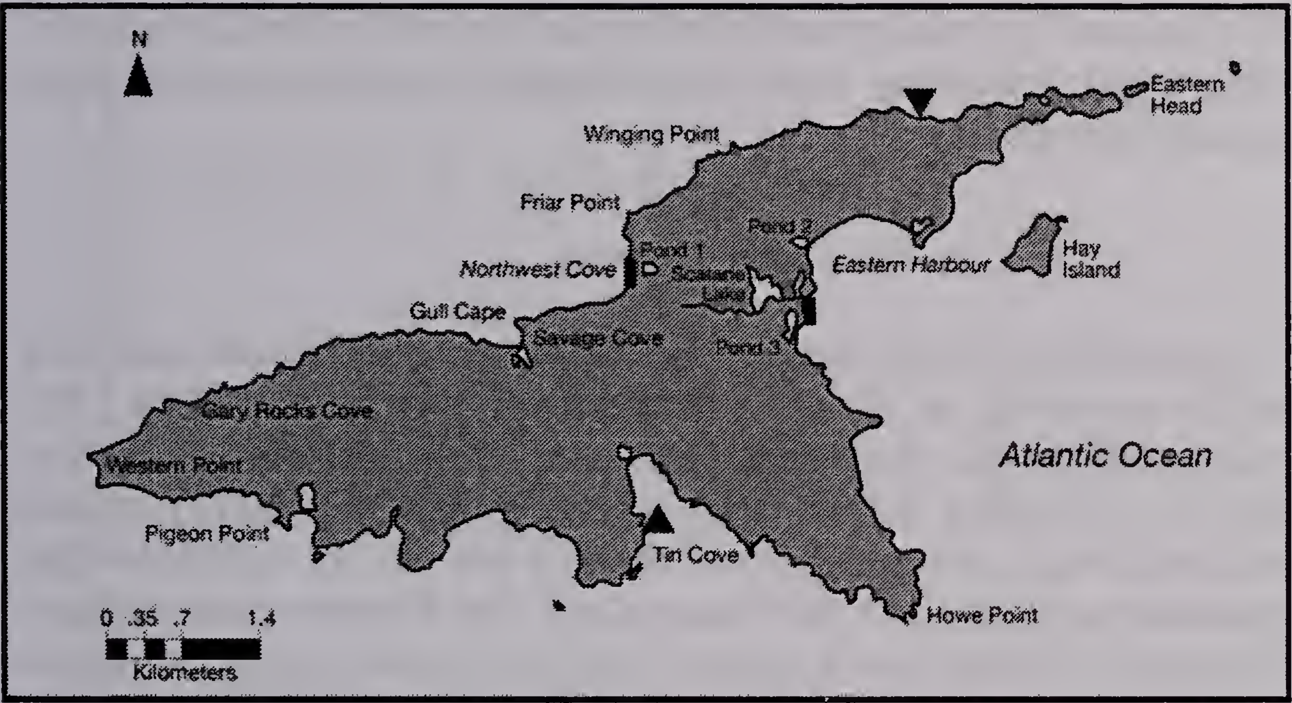


Fig 1 Study area of Scatarie Island illustrating Scatarie Lake and the three sampled ponds, two intertidal sampling locations (black rectangles) and two areas of transects of Moore et al. (1986) (black triangles).

communities were primarily *Fucus* sp., *Laminaria longicruris*, and *Saccorhiza dermatodea*, with lesser amounts of *Chondrus crispus, L. digitata*, and *Agarum cribrosum*.

Two coastal locations were sampled during the work described here: Northwest Cove and Eastern Harbour. Northwest Cove is a broad west-facing cove composed primarily of sand beach, grading to a small area of cobble beach at the north end. The beach drops off relatively rapidly creating conditions of moderate water depth near the shore. In contrast, Eastern Harbour is an east-facing sand beach interspersed with rocky headlands. Water depth is shallow as the beach gradient is low. Unlike Northwest Cove, Eastern Harbour appears to be a higher energy site based on the presence of gravel and cobble in the high intertidal zone.

There is limited freshwater on the island, and that which is present occurs primarily in isolated water bodies. The largest pond on the island (unnamed, but herein called Scatarie Lake) is approximately 10.5 ha. (Fig 1). There are also seven ponds between 2 and 6 ha, and approximately 22 small bodies of water <1.0 ha. Combined, these ponds form about 3.5% of the island area. These bodies of standing water are distributed primarily within two general land-forms: (1) bogs and barrens, and (2) in the low-lying areas behind the berms of coastal beaches. The ponds are largely isolated from each other with only Scatarie Lake having an appreciable inflow and outflow stream. The area drained by the Scatarie Lake catchment is approximately 81 ha (~5.5% of island). The water within the ponds is dark (colored), creating "brown-water" systems.

This feature is consistent with draining a bog and barren landscape. At the time of sampling, visibility in the water column was estimated as less than 15 cm.

METHODS

Two intertidal locations and four freshwater ponds were sampled for fish presence on Scatarie Island from 8-11 August 2005. Access and logistical constraints (few roads, no vehicle transportation and fish sampling being relatively equipment intensive) limited the sampling to the northern portion of the island, with intertidal sampling conducted at Northwest Cove and Eastern Harbour and freshwater sampling at Scatarie Lake and three unnamed ponds (herein called Ponds 1, 2, 3; see Fig 1 and Table 1). Sampling of the intertidal area was carried out by beach seine, Fyke net and minnow traps, while the freshwater sampling utilized only minnow traps. The beach seine (18 m long, mesh size 7 mm) was deployed only in Northwest Cove. No attempt was made to standardize the area swept by the net among sweeps, and the area enclosed was not estimated. A single Fyke net (3 m long, mouth of 0.40 m^2, mesh size 1.5 cm) was set either overnight (8-9 August) or for six hours (10 August) as convenient; no effort was made to set on a particular tide. Standard minnow traps were set in pairs at a given site and baited with beef liver. Those traps set within Scatarie Lake contained chemical light sticks ("glow sticks") the night of 8-9 August to aid in attracting fish; the following night attractants were not used. Generally, minnow traps were set overnight, though on occasion were lifted or retrieved before nightfall and moved to a new location. The sampling regime is summarized in Table 1.

Captured fish were identified to the level of species using Leim and Scott (1966), measured for length and returned to the water. Incidental mortalities and voucher specimens were retained as appropriate.

RESULTS

A total effort of 300 minnow trap-hours (127 hours in marine water, 173 in freshwater), 21 Fyke net-hours and four beach seine sets yielded nine species of intertidal or freshwater fish (Table 2). The most commonly captured fish were Atlantic herring (*Clupea harengus*), grubby (*Myoxocephalus aenaeus*), white hake (*Urophycis tenuis*), and cunner (*Tautogolabrus adspersus*). Other species encountered were a few nine-spine stickleback (*Pungitius pungitius*) and one each of winter flounder (*Pseudopleuronectes americanus*),

Table 1 Summary of fish sampling regime on Scatarie Island, 8-11 August 2005.

Date	Location	Coordinates (Lat/Long)	Capture method	Number set	Hours set	Effort (trap-hours)
8-9 August	Eastern Harbour	46°01.33' / 59°42.7'	Fyke net	1	15	15
8-9 August	Eastern Harbour	46°01.33' / 59°42.7'	Minnow trap	2	22	44
8-9 August	Scatarie Lake	46°01.32' / 59°43.23'	Minnow trap	2	15	30
8-9 August	Pond 1	46°01.48' / 59°44.24'	Minnow trap	2	11	22
8-9 August	Pond 2	not recorded	Minnow trap	2	15	30
9 August	Northwest Cove	46°01.31' / 59°43.92'	Beach seine	3	N/A	N/A
9-10 August	Eastern Harbour	46°01.17' / 59°42.71'	Minnow trap	2	16.5	33
9-10 August	Northwest Cove	46°01.31' / 59°43.92'	Minnow trap	2	14	28
9-10 August	Scatarie Lake	46°01.32' / 59°43.23'	Minnow trap	2	17	34
9-10 August	Pond 3	46°01.27' / 59°42.76'	Minnow trap	2	23	46
10 August	Northwest Cove	46°01.31' / 59°43.92'	Minnow trap	2	5.5	11
10 August	Northwest Cove	46°01.18' / 59°43.99'	Minnow trap	2	5.5	11
10 August	Northwest Cove	46°01.31' / 59°43.92'	Fyke net	1	6	6
10 August	Northwest Cove	46°01.31' / 59°43.92'	Beach seine	1	N/A	N/A
10 August	Pond 1	46°01.48' / 59°44.24'	Minnow trap	2	5.5	11
					Total = 321	

Table 2 Summary of results of intertidal and freshwater fish sampling on Scatarie Island, 8-11 August 2005.

Family	Species	Location	Method	Number captured	CPUE *
Intertidal					
Pleuronectidae	Winter flounder	Eastern Harbour	Fyke net	1	0.067
Gadidae	White hake	Eastern Harbour	Fyke net	1	0.067
		Eastern Harbour	Minnow trap	3	0.039
	Unidentified Hake	Northwest Cove	Beach seine	1	N/A
Cottidae	Grubby	Eastern Harbour	Minnow trap	8	0.104
Clupeidae	Atlantic herring	Northwest Cove	Beach seine	~650	N/A
	Blueback herring/Gaspereau	Northwest Cove	Beach seine	1	N/A
Labridae	Cunner	Northwest Cove	Minnow trap	2	0.040
		Northwest Cove	Beach seine	1	N/A
Scombridae	Atlantic mackerel	Northwest Cove	Beach seine	1	N/A
Freshwater					
Gasterostidae	9-spine stickleback	Pond 1	Minnow trap	1	0.030
		Pond 3	Minnow trap	3	0.065

* CPUE = catch per unit effort

blueback herring or gaspereaux (*Alosa* sp.), Atlantic mackerel (*Scomber scombrus*), and an unidentified hake (*Urophycis* sp.). This hake was retained and submitted to L. Van Guelpen (Curator of Fishes and Collections Manager, Atlantic Reference Centre, Huntsman Marine Science Centre, St Andrews, New Brunswick) for positive identification. This fish could not be positively identified as a spotted hake (*U. regia*) or white hake and its identity remains uncertain. (It is archived at the Atlantic Reference Centre). Catch per unit effort (CPUE) for the minnow traps was low, ranging between 0.03 and 0.10 fish/trap-hour. Lengths of captured fish by species are presented in Figure 2.

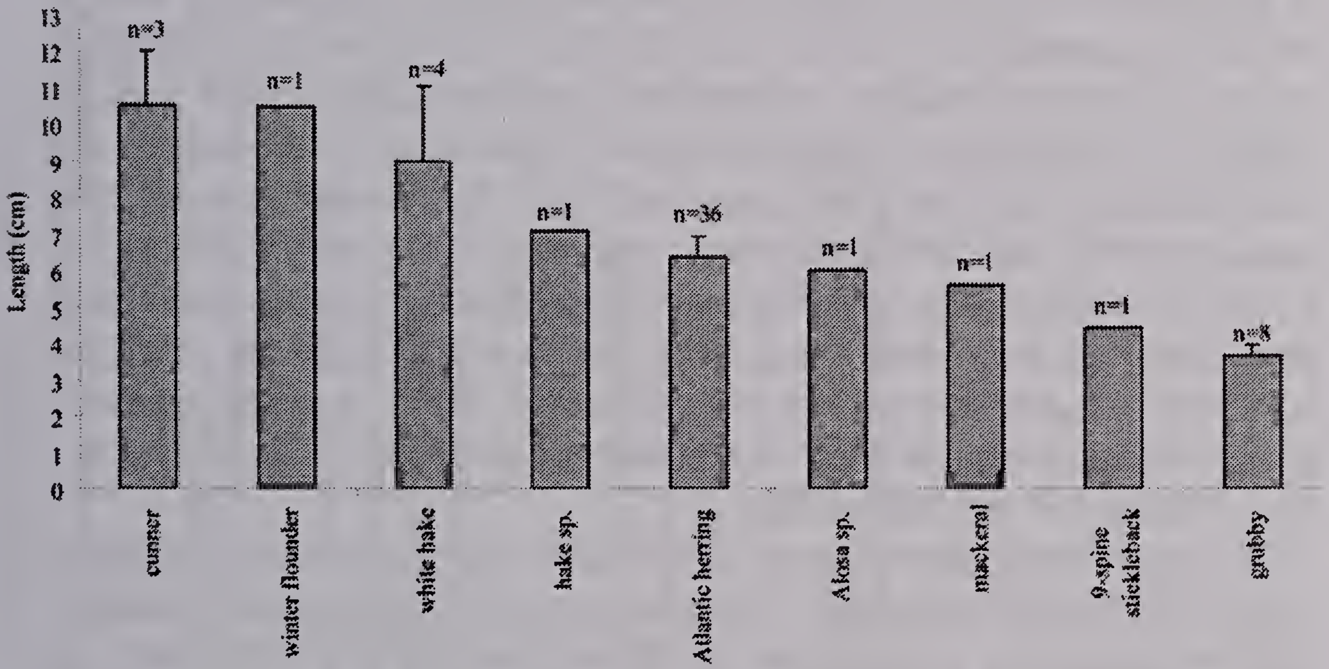


Fig 2 Mean length of captured fish species from Scatarie Island. Measure is total length except herring, Alosa sp, and mackerel which are fork length. Error bars are SD, where appropriate. Values indicate number of fish in sample.

In addition to the fish species described above, three observations are relevant in interpreting fish distributions on Scatarie Island. Tadpoles of a frog species, tentatively identified as green frog (*Rana clamitans*), were captured in minnow traps in Pond 2. This indicates that this pond is freshwater and not significantly influenced by salinity; therefore, wholly freshwater or euryhaline species such as sticklebacks would be expected here. Second and surprisingly no fish were captured in Scatarie Lake, the largest body of freshwater on the island. This despite 64 trap-hours (37% of total freshwater sampling) expended here. It is premature to state that it is fishless, but the capture methodology used did not show any fish presence. Finally, a limitation of the minnow trap as a sampling tool was demonstrated at Pond 3 where, after eight hours the traps were lifted and two sticklebacks were present in one trap. The traps were replaced with the fish in them and the following morning checked again (total set time 23 hours). The trap which had contained the two fish now had none, and the trap originally with zero fish had one stickleback. Clearly, these small fish in the freshwater environment were easily getting in and out of the trap.

DISCUSSION

The freshwaters of Scatarie Island contained only a single known fish species, the nine-spine stickleback. This low species richness is explained by the isolated nature of islands, requiring a fish to tolerate seawater in order to colonize [the nine-spine stickleback is found in both freshwater and marine environments (Scott & Scott 1988)]. In the case of Scatarie Island, colonization difficulty is exacerbated by the low relief, bog nature of the landscape creating slow-moving, dark water streams unsuitable for many diadromous species. Island biogeography theory maintains that both island size and distance from mainland have profound effects on colonization rate. Scatarie Island is a small island close to a larger island (Cape Breton) which itself has reduced diversity. Therefore, the low richness is not surprising.

The capture of sticklebacks in Ponds 1 and 3, but not in Scatarie Lake is difficult to reconcile. The freshwater ponds appear isolated, with no apparent connection to other freshwater bodies and yet these contain fish.

The intertidal fish species richness in the waters of the island, based on the limited sampling conducted during the short window of opportunity, is relatively high for the northwest Atlantic. With any survey sampling, the number of species captured/observed is expected to rise with effort to an asymptote beyond which further effort yields very few additional species. Although that asymptote probably was not reached in the current study, the eight intertidal species are likely to have included the majority of the species present. Table 3 shows other studies evaluating intertidal and shallow sub-tidal fish communities in the northwest Atlantic from which it may be seen that even with great effort (i.e., multiple years) the fish species encountered remains below 30.

All marine species were captured at low abundance (low CPUE) with the exception of Atlantic herring. The much greater abundance of herring versus the other species results from their traveling in large schools (Scott & Scott 1988); when these are intercepted the yield is large.

Table 3 Summary of previous relevant studies on shallow inshore fish community composition.

Study	Location	Effort/methods	Number of species encountered	Species in common with Scatarie Island
Tyler (1971)	Passamaquoddy Bay, New Brunswick	204 hours television observation of intertidal	9	Atlantic herring Winter flounder
Black and Miller (1991)	Yarmouth County, Nova Scotia	6 sampling periods (early June-October) using trammel nets (135 sets) and beach seines (52 sets)	18	White hake Gaspereau Atlantic mackerel Cunner Grubby
Lazzari et al. (1999)	Kennebeck Point, Maine	Bi-weekly Fyke net and beach seine samples, April-Dec., 1990-1994 (320 samples)	27	Atlantic herring White hake *Alosa* sp. Nine-spine stickleback
Stokesbury and Stokesbury (1999)	Baie des Chaleurs, Quebec	Trammel nets and gill nets (sub-tidal) 679 sampling hours over two years	22 22	Atlantic herring White hake Winter flounder Cunner

This fish sampling provided a reconnaissance level survey of a few isolated locations on the island. Future survey trips should use a boat to access other coves and rocky headlands to sample with beach seine and minnow traps. In addition, snorkeling gear would add visual assessment for other species possibly missed by this sampling. Scatarie Lake should be sampled using fine mesh hand nets along the shoreline and minnow traps modified to a much finer mesh to contain very small fish. The use of a Fyke net and set lines in Scatarie Lake to provide further information on whether, in fact, it is truly fishless is also recommended.

Acknowledgements. I thank Robert Cameron and Dave Williams (Protected Areas Branch, Nova Scotia Department of Environment and Labor) for organizing and arranging this "bio-blitz" – a thoroughly enjoyable and educational way to conduct scientific research. I also thank Jim Williams (St. Francis Xavier University) for the loan of sampling gear and Lou van Guelpen (Atlantic Reference Centre).

REFERENCES

Black R, Miller RJ (1991) Use of the intertidal zone by fish in Nova Scotia. *Environmental Biology of Fishes* 31(2):109-121.

Davis DS, Browne S (1996) The natural history of Nova Scotia, 2 vols, rev ed. Nova Scotia Museum and Nimbus Publishing, Halifax, Nova Scotia.

Leim AH, Scott WB (1966) Fishes of the Atlantic coast of Canada. Bulletin. Fisheries Research Board Canada. No.155.

MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton, NJ.

Moore DS, Miller RJ, Meade LD (1986) Survey of shallow benthic habitat: Eastern Shore and Cape Breton, Nova Scotia. Canadian Technical Report of Fisheries and Aquatic Sciences 1546.

Scott WB, Crossman EJ (1973) Freshwater fishes of Canada. Bulletin. Fisheries Research Board Canada No. 184.

Scott WB, Scott MG (1988). Atlantic fishes of Canada. Bulletin. Fisheries Research Board Canada No. 219.

Stokesbury KDE, Stokesbury MJW (1999) Subtidal fishes associated with gravel and bedrock in the Baie des Chaleurs, Québec. *Canadian Field Naturalist* 113(3):466-471.

Tyler AV (1971) Surges of winter flounder, *Pseudopleuronectes americanus*, into the intertidal zone. *Journal of the Fisheries Research Board of Canada* 28(11):1727-1732.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 45-68

A CHECKLIST OF VASCULAR PLANTS FROM SCATARIE ISLAND, NOVA SCOTIA

JONATHAN FERRIER[1]*, A. ANDREW M. MACDONALD[2]
AND BARRY R. TAYLOR[1]
[1]*Department of Biology*
St. Francis Xavier University
Antigonish, Nova Scotia B2G 2W5

[2]*Department of Biology*
Cape Breton University
Sydney, Nova Scotia B1P 6L2

A vascular plant survey of Scatarie Island, Nova Scotia was conducted from 8 to 11 August 2005. Our expedition gathered 77 vascular plant collections that were deposited in the Saint Francis Xavier (STFX) and Cape Breton University (CBUH) herbaria. A Scatarie Island Vascular Plant Checklist was compiled, combining our survey and three previous vascular plant surveys for a total of 309 species extending the checklist by 15 species. There are now 203 species on the checklist represented by voucher specimens and 106 species not represented by voucher specimens which remain on the list. The island supports a number of plant species that are of special interest because of their rarity in the region, especially those with an arctic or alpine affiliation.

Une étude des plantes vasculaires de l’île Scatarie, en Nouvelle-Écosse, a été effectuée du 8 au 11 août 2005. L’expédition a permis de recueillir 77 collections de plantes vasculaires qui ont été déposées dans les herbiers de l’Université Saint Francis Xavier et de la Cape Breton University. Une liste des plantes vasculaires de l’île Scatarie a été dressée, à partir de notre étude et de trois études précédentes menées sur les plantes vasculaires. La liste s’est enrichie de 15 espèces supplémentaires et compte au total 309 espèces. Sur ces 309 espèces, 203 sont maintenant représentées par des spécimens de référence et 106 espèces pour lesquelles on n’a pas de spécimens de référence restent sur la liste. L’île abrite plusieurs espèces végétales qui présentent un intérêt particulier compte tenu de leur rareté dans la région, particulièrement celles qui sont associées aux zones arctiques ou alpines.

INTRODUCTION

Scatarie Island is a provincial protected Wilderness Area located off the north-eastern coast of Cape Breton, Nova Scotia (Province of Nova Scotia 2006); the island is known for its rare bird and plant species (Cameron 2004). Most of the island is boreal forest, a characteristic of locations near the Atlantic coast (Loucks 1961, Davis & Browne 1998). Near the coast the forest gives way to barrens, salt marshes, and wetlands while the hilly interior is covered with exposed taiga, bogs and fens. In most of these habitats, the same species of introduced and native plants are common on Scatarie Island as on the mainland; however, Scatarie Island is also home to many provincial rarities. These species are typically adapted to more northerly climates and persist in the harsh climate of Scatarie Island (Davis & Browne 1998). This checklist combines past vascular plant surveys with our recent survey to provide a current checklist of the Island's vascular flora which will aid future inquiry into the vascular plants and the ecosystem of Scatarie Island.

---

* Author to whom correspondence should be addressed.
Email: jonathanferrier@gmail.com

METHODS

Between 09 and 11 August 2005, Scatarie Island was explored on foot as part of a volunteer "Bioblitz" expedition. Collections of vascular plants were made within three kilometres of Northwest Cove, using an unpublished species checklist as a guide (Williams 2000). This checklist was compiled using unpublished records from previous explorations of Scatarie Island (Table 1). Plants were collected, habitat details were recorded, and plants were pressed immediately. Identifications were made in the field using Roland and Smith (1966, 1969), or in a herbarium with the aid of dissecting microscopes, using Roland (1998), and collections at Saint Francis Xavier (STFX) and Cape Breton University (CBUH).

Table 1 A list of previous collection trips to Scatarie Island. Date, collectors' names and repository of their specimens are supplied. ACAD = E. C. Smith Herbarium, Acadia University, Wolfville; CBUH = Cape Breton University Herbarium, Sydney; NSPM = Nova Scotia Provincial Museum, Halifax; STFX = St. Francis Xavier University Herbarium, Antigonish.

Year	Collectors	Herbarium
1951	Erskine, JS	NSPM
1951	Smith, EC, Schofield, WB, Sampson, DR, Bent, FC	ACAD
1953	Smith, EC, Schofield, WB, Taylor, JC, Webster, DH, Slipp, LB and Bently, PA	ACAD & NSPM
1953	Smith, EC, Taylor, JC, Webster, DH, Slipp, LB and Schofield, WB	ACAD & NSPM
1971	Godfrey, AP	none
1984	Williams, M	NSPM & CBUH
1992	Crins, WJ and McCorquodale, DB	CBUH
1995	Williams, M and Currie, N	CBUH & ACAD
2005	Ferrier, J, MacDonald, AAM and Taylor, BR	STFX & CBUH

The habitats sampled included dense coniferous forests, grassy dunes, coastal headlands and barrens, inland barrens, barrachois, bogs, and roadsides. On 09 August a route was explored starting at Northwest Cove through the forest and barrens to Tin Cove. From Tin Cove the route extended southeast along the coast and across the peninsula northeast of Howe Point. The route continued along the coast as far as Eastern Harbour and back to Northwest Cove. On 10 August three areas were explored: the coast at Savage point, the nearby plateau-taiga hilltops, and the forest and brackish lakes southeast of Northwest Cove.

Voucher specimens were deposited at STFX and CBUH, labelled with the plant's scientific and common names, collection date, GPS coordinates, habitat, collector, identifier, and a herbarium specimen number. All species names and authorities of past surveys were updated using Roland (1998).

RESULTS

The complete vascular plant checklist for Scatarie Island, including new collections, is given in Table 2. This list comprises 308 species in 68 families. Of these, fifteen species are new to the checklist. Specimens of twelve of these were collected: *Carex disperma, Epilobium hornemannii, Goodyera tesselata, Ilex glabra*, *Moneses uniflora*, *Monotropa uniflora*, *Plantanthera obtusata, Listera cordata*, *Pyrola elliptica*, *Scirpus acutus*, *Scirpus maritimus* and *Taxus canadensis*. We observed, but did not collect three previously unreported species: *Atriplex patula*, *Larix laricina* forma *depressa*, and *Typha latifolia*. Some 106 plants were included in the checklist based on unpublished sources (Table 1), despite the absence of voucher specimens.

We also found several colonies of rare plants and recorded their GPS coordinates, only collecting where plants were abundant (Table 3). We define rare plants as those that are numerically infrequent at some spatial scale. The Atlantic Canada Conservation Data Centre (ACCDC) maintains a list of rare plants in the province, while the Nova Scotia Department of Natural Resources (DNR) has classified most species according to the degree to which their provincial populations are at risk of extirpation, as green (secure), yellow (vulnerable) or red (threatened). Rarity is only one element determining whether a species is at risk.

We report three populations of *Vaccinium uliginosum* and one of *V. boreale*, as well as confirming the continued presence of *Cornus suecica* at Northwest Cove. The GPS coordinates in Table 3 can be used by future researchers to locate and monitor the survival of these populations.

Table 2 A vascular plant list for Scatarie Island. Data are compiled from unpublished sources, four Nova Scotia herbaria, and our own collections (†). Our new additions to the list are indicated with an asterisk (*). Numbers in columns indicate the number of specimens at each herbarium. Note that some species on the list are not represented by collections and have been included based on unpublished resources. We observed but did not collect three of these species (indicated with ~).

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Apiaceae		*Angelica sylvestris*	L.	Woodland angelica		1		
Apiaceae		*Carum carvi*	L.	Caraway				1
Apiaceae		*Cicuta bulbifera*	L.	Bulbous water-hemlock				
Apiaceae	†	*Ligusticum scothicum*	L.	Scotch lovage	1	1		
Apiaceae	†	*Sium suave*	L.	Water-parsnip	1			
Aquifoliaceae	†*	*Ilex glabra*	(L.) Gray	Inkberry		1		
Aquifoliaceae		*Ilex verticillata*	(L.) Gray	Canada holly				
Aquifoliaceae		*Nemopanthus mucronata*	(L.) Trel.	False holly				
Araliaceae		*Aralia hispida*	Vent.	Bristly aralia		1		
Asteraceae	†	*Achillea millefolium*	L.	Yarrow	1	1		
Asteraceae		*Ambrosia artemisiifolia*	L.	Common ragweed				
Asteraceae		*Anaphalis margaritacea*	(L.) Benth. & Hook.	Pearly everlasting		1		
Asteraceae		*Antennaria neglecta var. neodioica*	(Green) Cronq.	Everlasting				
Asteraceae		*Aster acuminatus*	Michx.	Wood aster				
Asteraceae	†	*Aster nemoralis*	Ait.	Bog aster		1		
Asteraceae	†	*Aster novi-belgii*	L.	New York aster	1			
Asteraceae		*Aster radula*	Ait.	Low rough aster		1		
Asteraceae		*Bidens frondosa*	L.	Common beggar's ticks				
Asteraceae		*Chrysanthemum leucanthemum*	L.	Ox-eye daisy				
Asteraceae		*Cirsium vulgare*	(Savi) Tenore	Bull thistle				1
Asteraceae		*Gnaphalium uliginosum*	L.	Low cudweed				1
Asteraceae		*Gnaphalium sylvaticum*	L.	Cudweed				
Asteraceae		*Hieracium caespitosum*	Dumort	Meadow hawkweed				1
Asteraceae		Hieracium floribundum	Wimm. & Grabb.	King-devil				

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Asteraceae		*Hieracium murorum*	L.	Wall hawkweed				1
Asteraceae		*Hieracium pilosella*	L.	Mouse-ear hawkweed				1
Asteraceae	†	*Leontodon autumnalis*	L.	Fall dandelion		1		1
Asteraceae		*Matricaria maritima*	(Less.) Porter	Mayweed				1
Asteraceae		*Matricaria matricarioides*	(Less.) Porter	Pinapple-weed				1
Asteraceae		*Prenanthes altissima*	L.	Tall rattlesnake-root				
Asteraceae	†	*Prenanthes nana*	(Bigel) Torr.	Dwarf rattlesnake-root	1	1		
Asteraceae		*Prenanthes trifoliolata*	(Cass.) Fern.	Lion's-paw				
Asteraceae		*Senecio jacobaea*	L.	Ragwort				
Asteraceae		*Solidago nemoralis*	Ait.	Old-field goldenrod				
Asteraceae		*Solidago puberula*	Nutt.	Rough goldenrod				
Asteraceae		*Solidago rugosa*	Ait.	Rough goldenrod				
Asteraceae	†	*Solidago sempervirens*	L.	Seaside goldenrod		1		
Asteraceae	†	*Solidago uliginosa*	Nutt.	Bog goldenrod		1		
Asteraceae		*Sonchus arvensis*	L.	Perennial sow-thistle				1
Asteraceae		*Sonchus asper*	(L.) Hill	Spiny sow-thistle				1
Asteraceae		*Sonchus oleraceus*	L.	Annual sow-thistle				
Asteraceae		*Tanacetum vulgare*	L.	Tansy				1
Asteraceae		*Taraxacum officinale*	Weber	Common dandelion				1
Asteraceae		*Tussilago farfara*	L.	Coltsfoot				
Balsaminaceae	†	*Impatiens capensis*	Meerb.	Spotted touch-me-not	1			
Betulaceae		*Alnus incana*	(L.) Moench	Alder				
Betulaceae	†	*Alnus viridis*	(Villars) Lamb.	Alder		1	1	
Betulaceae		*Betula alleghaniensis*	Britt.	Yellow birch				
Betulaceae	~	*Betula cordifolia*	Regel	Heart-leaved birch				
Betulaceae		*Betula papyrifera*	Marsh.	Paper birch		1		
Boraginaceae		*Mertensia maritima*	(L.) S.F.Gray	Sea-lungwort		1		

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Brassicaceae		*Cakile edentula*	(Bigel.) Hook	Sea-rocket		1	2	
Brassicaceae		*Capsella bursa-pastoris*	(L.) Medikus	Shepard's purse				1
Brassicaceae		*Cardamine parviflora*	L.	Sand bittercress				
Callitrichaceae		*Callitriche palustris*	L.	Water starwort				
Campanulaceae		*Campanula rotundifolia*	L.	Hare-bell		1		
Caprifoliaceae		*Diervilla lonicera*	P. Mill.	Bush honeysuckle				
Caprifoliaceae		*Linnaea borealis*	L.	Twinflower				
Caprifoliaceae		*Lonicera villosa*	(Michx.) R. & S.	Moutain fly-honeysuckle		1		
Caprifoliaceae	†	*Viburnum nudum*	L.	Witherod		1		
Caryophyllaceae		*Arenaria lateriflora*	L.	Sandwort		1	3	
Caryophyllaceae		*Cerastium vulgatum*	L.	Mouse-eared chickweed		1	2	1
Caryophyllaceae		*Cirsium arvense*	(L.) Scop.	Canada thistle				1
Caryophyllaceae		*Honckenya peploides*	(L.) Ehrh.	Seabeach-sandwort		1	2	
Caryophyllaceae		*Sagina procumbens*	L.	Pearlwort				
Caryophyllaceae	†	*Spergularia marina*	(L.) Griseb.	Salt sand-spurry	1		1	
Caryophyllaceae		*Spergularia rubra*	(L.) J. & C. Presl.	Sand-spurry				1
Caryophyllaceae		*Stellaria graminea*	L.	Stitchwort				
Caryophyllaceae		*Stellaria humifusa*	Rottb.	Saltmarsh starwort			1	1
Caryophyllaceae		*Stellaria media*	(L.) Cyrillo	Common chickweed				1
Chenopodiaceae	~	*Atriplex patula*	L.	Orach				
Chenopodiaceae		*Salicornia europaea*	L.	Glasswort				
Chenopodiaceae		*Suaeda maritima*	(L.) Dumort	Sea-blite				
Clusiaceae		*Hypericum boreale*	(Britton) E. Bickn.	Northern St. John's-wort				
Clusiaceae	†	*Hypericum canadense*	L.	Lesser Canadian St. John's-wort	1			
Clusiaceae	†	*Triadenum fraseri*	(Spach) Gleason	Marsh St. John's-wort	1	1		

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Clusiaceae		*Triadenum virginicum*	(L.) Raf.	Virginia marsh St. John's-wort		1		1
Convolvulaceae		*Calystegia sepium*	R.Br.	Hedge false bindweed				
Cornaceae		*Cornus canadensis*	L.	Bunchberry		1		
Cornaceae	†	*Cornus suecica*	L.	Lapland cornel	1	1	1	1
Cornaceae	†	*Cornus x intermedia*	(Farr) Calder & Roy L. Taylor			1		
Crassulaceae		*Crassula aquatica*	(L.) Schonl.	Pygmy-weed			1	1
Cupressaceae	†	*Juniperus communis var. depressa*	Pursh	Ground juniper	1	1	1	1
Cupressaceae	†	*Juniperus horizontalis*	Moench	Creeping juniper	1		1	1
Cyperaceae		*Carex brunnescens*	(Pers.) Poiret	Sedge				
Cyperaceae		*Carex canescens*	L.	Sedge				
Cyperaceae	†*	*Carex disperma*	Dewey	Sedge	1			
Cyperaceae		*Carex echinata*	Murray	Sedge				
Cyperaceae		*Carex exilis*	Dewey	Sedge				
Cyperaceae		*Carex folliculata*	L.	Sedge			1	
Cyperaceae		*Carex hormathodes*	Fern.	Sedge			1	
Cyperaceae		*Carex leptalea*	Wahlemb.	Sedge				
Cyperaceae		*Carex limosa*	L.	Sedge				
Cyperaceae		*Carex nigra*	(L.) Reichard	Sedge		1		
Cyperaceae		*Carex paleacea*	Schreber.	Sedge				
Cyperaceae		*Carex pauciflora*	Lightf.	Sedge				
Cyperaceae	†	*Carex paupercula*	Michx.	Sedge	1	1	1	
Cyperaceae	†	*Carex rariflora*	(Wahl.) Smith	Sedge		1	2	1
Cyperaceae	†	*Carex recta*	Boott	Sedge		1		
Cyperaceae	†	*Carex rostrata*	Stokes	Sedge	1		3	
Cyperaceae		*Carex scoparia*	Schkuhr	Sedge				

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Cyperaceae		*Carex trisperma*	Dewey	Sedge				
Cyperaceae		*Carex viridula*	Michx.	Sedge				
Cyperaceae		*Eleocharis halophila*	(Fern. & Black) Fern. & Black	Spike-rush			1	
Cyperaceae		*Eleocharis nitida*	Fern.	Spike-rush			1	1
Cyperaceae		*Eleocharis smallii*	(L.) R & S	Spike-rush			1	
Cyperaceae		*Eriophorum polystachion*	L.	Cotton-grass				
Cyperaceae		*Eriophorum tenellum*	Nutt.	Cotton-grass				
Cyperaceae		*Eriophorum viridi-carinatum*	(Engelm.) Fern.	Cotton-grass				
Cyperaceae		*Eriophorum spissum*	Fern.	Hare's tail			1	
Cyperaceae		*Eriophorum vaginatum*	L.	Cotton-grass		1	1	
Cyperaceae	†	*Eriophorum virginicum*	L.	Tawny cotton-grass	1		1	
Cyperaceae	†	*Rhynchospora alba*	(L.) Vahl	Beak-rush	1	1	1	
Cyperaceae		*Rhynchospora fusca*	(L.) Aiton f.	Beak-rush				
Cyperaceae	†*	*Scirpus acutus*	Muhl.	Bulrush	1			
Cyperaceae		*Scirpus atrocinctus*	L. Kunth	Bulrush				
Cyperaceae	†	*Scirpus caespitosus*	L.	Deergrass		1	1	
Cyperaceae	†*	*Scirpus maritimus*	L.	Saltmarsh bulrush	1			
Cyperaceae	†	*Scripus validus*	Vahl	Bulrush	1		1	
Dennstaedtiaceae		*Dennstaedtia punctilobula*	(Michx.) Moore	Hay-scented fern				1
Dennstaedtiaceae		*Pteridium aquilinum*	(L.) Kuhn.	Bracken			1	1
Droseraceae	†	*Drosera intermedia*	Hayne	Narrow-leaved sundew		1		
Droseraceae	†	*Drosera rotundifolia*	L.	Round-leaved sundew	1	1		
Dryopteridaceae		*Dryopteris carthusiana*	(Vill.) Fuchs	Spinulose woodfern				1
Dryopteridaceae		*Dryopteris cristata*	(L.) Gray	Crested wood-fern				1
Empetraceae		*Empetrum nigrum*	L.	Black crowberry		1		
Equisetaceae		*Equisetum arvense*	L.	Field horsetail				1

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Equisetaceae	†	*Equisetum fluviatile*	L.	Water horsetail	1			1
Equisetaceae		*Equisetum sylvaticum*	L.	Wood horsetail			1	1
Equisetaceae		*Equisetum X litorale*	Kuhl.	Hybrid horsetail		1		
Ericaceae	†	*Andromeda glaucophylla*	Link	Bog-rosemary	1	1		
Ericaceae		*Chamaedaphne calyculata*	(L.) Moench	Leather leaf				
Ericaceae	†	*Gaultheria hispidula*	(L.) Muhl.	Creeping snowberry	1	1		
Ericaceae		*Gaultheria procumbens*	L.	Teaberry				
Ericaceae		*Gaylussacia baccata*	(Wang.) K. Koch	Huckleberry		1		
Ericaceae	†	*Gaylussacia dumosa*	(Andr.) T&G	Bog huckleberry	1	1		
Ericaceae		*Kalmia angustifolia*	L.	Lambkill				
Ericaceae		*Kalmia polifolia*	Wang.	Bog laurel		1		
Ericaceae	†	*Ledum groenlandicum*	Oeder.	Labrador tea	1	1		
Ericaceae		*Rhododendron canadense*	(L.) Torr.	Rhodora				
Ericaceae		*Vaccinium oxycoccus*	L.	Small cranberry				
Ericaceae		*Vaccinium angustifolium*	Ait.	Blueberry				
Ericaceae		*Vaccinium boreale*	Hall & Aalders	Northern blueberry				1
Ericaceae	†	*Vaccinium macrocarpon*	Ait.	Large cranberry		1		
Ericaceae	†	*Vaccinium uliginosum*	L. var. alpinum Bigelow	Alpine whortleberry	1	1	1	1
Ericaceae	†	*Vaccinium vitis-idaea*	L.	Foxberry	1			
Eriocaulaceae		*Eriocaulon aquaticum*	(Hill) Druess.	Pipwort				
Fabaceae		*Lathyrus maritimus*	(L.) Bigelow	Beach pea		1		
Fabaceae		*Trifolium hybridum*	L.	Alsike clover				1
Fabaceae		*Trifolium pratense*	L.	Red clover				1
Fabaceae	†	*Trifolium repens*	L.	White clover		1		1
Fabaceae		*Vicia cracca*	L.	Vetch				1
Gentianaceae		*Bartonia paniculata*	(Michx.) Muhl.	Screw-stem				

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Gentianaceae		*Halenia deflexa*	(Sm.) Griseb.	Spurred gentian			1	1
Gentianaceae		*Menyanthes trifoliata*	L.	Buckbean				
Hippuridaceae	†	*Hippuris vulgaris*	L.	Mare's-tail	1	1		
Iridaceae	†	*Iris setosa*	Pallas	Beachhead iris		1	3	
Iridaceae		*Iris versicolor*	L.	Blue flag iris		1	2	
Iridaceae	†	*Sisyrinchium montanum*	Greene	Blue-eyed grass		1		
Isoetaceae		*Isoetes echinospora*	Dur.	Quillwort				1
Isoetaceae		*Isoetes tuckermani*	A. Br.	Quillwort				
Juncaceae		*Juncus brevicaudatus*	(Engelm.) Fern.	Rush				
Juncaceae		*Juncus bufonius*	L.	Toad rush				
Juncaceae	†	*Juncus effusus*	L.	Soft rush		1	1	
Juncaceae		*Juncus filiformis*	L.	Rush				
Juncaceae		*Juncus militaris*	Bigelow	Rush				
Juncaceae		*Juncus pelocarpus*	E. Mayer	Rush				
Juncaceae		*Juncus tenius*	Willd.	Rush				
Juncaceae		*Luzula multiflora*	(Retz.) Lejeune	Common woodrush				
Juncaginaceae		*Triglochin maritima*	L.	Arrow-grass				
Lamiaceae		*Galeopsis tetrahit*	L.	Hemp-nettle				1
Lamiaceae		*Mentha arvensis*	L.	Field mint				
Lamiaceae	†	*Scutellaria galericulata*	L.	Marsh-skullcap	1	1		
Lentibulariaceae	†	*Utricularia cornuta*	Michx.	Bladder-wort	1	1		
Lentibulariaceae		*Utricularia geminiscapa*	Benj.	Bladder-wort				
Lentibulariaceae		*Utricularia vulgaris*	L.	Bladder-wort				
Lilaceae		*Allium schoenoprasum var. sibiricum*	L.	Wild chives			1	
Lilaceae		*Clintonia borealis*	(Aiton.) Raf.	Blue-bead lily				
Lilaceae		*Maianthemum canadense*	Desf.	Wild lily-of-the-valley				

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Lilaceae		*Smilacina stellata*	(L.) Desf.	Starry false solomon's seal		1	3	
Lilaceae	†	*Smilacina trifolia*	(L.) Desf.	Three-leaved false solomon's seal	1	1	1	
Linaceae		*Radiola linoides*	Roth.	Tiny all-seed		1		1
Lycopodiaceae		*Lycopodium annotinum*	L.	Bristly club-moss				1
Lycopodiaceae	†	*Lycopus uniflorus*	Michx.	Northern bugleweed		1		
Monotropaceae	†	*Monotropa hypopithys*	L.	Pine-sap	1	1		
Monotropaceae	†*	*Monotropa uniflora*	L.	Indian-pipe		1		
Myricaceae	†	*Myrica gale*	L.	Sweet gale	1	1		
Myricaceae	†	*Myrica pennsylvanica*	Mirbell.	Bayberry		1		
Nymphaeaceae	†	*Nuphar variegata*	Durand	Cow-lily	1		1	
Nymphaeaceae	†	*Nuphar X rubrodisca*	rubrodisca Morong	Yellow pond-lily		1	1	
Nymphaeaceae	†	*Nymphaea odorata*	Aiton	Water-lily	1			
Onagraceae	†	*Circaea alpina*	L.	Small enchanter's nightshade	1			
Onagraceae		*Epilobium glandulosum*	Lehm.	Willow-herb				
Onagraceae	†	*Epilobium angustifium*	L.	Fireweed	1			
Onagraceae	†	*Epilobium ciliatum*	Raf	Fringed willow-herb	1	1		
Onagraceae	†*	*Epilobium hornemannii*	Reichenb.	Hornemann's willow-herb	1			
Onagraceae	†	*Epilobium leptophyllum*	Raf.	Bog willow-herb	1	1		
Onagraceae	†	*Epilobium palustre*	L.	Marsh willow-herb		1		
Onagraceae		*Oenothera biennis*	L.	Evening primrose				
Onagraceae	†	*Oenothera parviflora*	L.	Small-flowered evening-primrose		1		
Onagraceae		*Trientalis borealis*	Raf.	Starflower				
Orchidaceae		*Arethusa bulbosa*	L.	Arethusa			1	

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Orchidaceae		*Calopogon pulchellus*	R. Br.	Calopogon			1	
Orchidaceae		*Calopogon tuberosus*	(L.) BSP	Calopogon		1		1
Orchidaceae	†*	*Goodyera tesselata*	Lodd.	Checkered rattlesnake plantain	1			
Orchidaceae	†*	*Listera cordata*	(L.) R. Br.	Heart-leaved twayblade	1	1		
Orchidaceae		*Malaxsis unifolia*	Michx.	Adder's mouth				1
Orchidaceae	†	*Plantanthera clavellata*	(Michx.) Luer	Northern club-spur	1			1
Orchidaceae	†*	*Plantanthera obtusata*	(Banks) Lindl.	Blunt-leaved rein orchid	1			
Orchidaceae		*Platanthera lacera*	(Michx) G. Don.	Ragged fringed orchid				1
Orchidaceae	†	*Pogonia ophioglossoides*	(L.) Ker-Gawler	Rose pogonia	1			1
Orchidaceae		*Spiranthes romanzoffiana*	Cham.	Hooded ladies'-tresses			1	1
Osmundaceae		*Osmunda cinnamomea*	L.	Cinnamon fern				1
Osmundaceae		*Osmunda regalis var spectabilis*	(Willd) Gray	Royal fern				1
Pinaceae		*Abies balsamea*	(L.) Mill	Balsam-fir		1		1
Pinaceae		*Abies balsamea var phanerolepis*	Fern.	Balsam-fir		1		1
Pinaceae		*Larix laricina*	(DuRoi) K. Koch	Larch				1
Pinaceae	~	*Larix laricina forma depressa*	Rousseau	Tamarack				
Pinaceae		*Picea glauca*	(Moench) Voss	White spruce				1
Pinaceae		*Picea mariana*	(Mill.) BSP	Black spruce			1	1
Plantaginaceae		*Plantago major*	L.	Soldier's plantian				
Plantaginaceae	†	*Plantago maritime*	L.	Seashore plantain	1	1		
Poaceae		*Agrostis canina*	L.	Velvet bent-grass				1
Poaceae		*Agrostis gigantean*	Roth	Red-top				
Poaceae		*Agrostis hyemalis*	(Walter) BSP	Bentgrass				
Poaceae		*Alopecurus geniculatus*	L.	Water-foxtail				1
Poaceae		*Ammophila breviligulata*	Fern.	American beach-grass				
Poaceae		*Anthoxanthum odoratum*	L.	Sweet vernal-grass				1

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Poaceae	†	*Calamagrostis Canadensis*	(Michx.) Beauv.	Blue-joint	1		1	
Poaceae		*Calamagrostis pickeringii*	Gray	Pickering's reedgrass		1		
Poaceae		*Danthonia spicata*	(L.) Beauv.	Wire-grass				
Poaceae		*Deschampsia flexuosa*	(L.) Trin.	Wavy hair-grass		1	1	
Poaceae	†	*Elymus mollis*	Trin.	American dune-grass		1	1	
Poaceae		*Elymus repens*	Gould	Quack-grass				1
Poaceae		*Elymus trachycaulus*	(Link) Gould	Slender wheatgrass		1	1	
Poaceae		*Festuca rubra*	L.	Red fescue				
Poaceae	†	*Glyceria Canadensis*	(Michx.) Trin.	Rattlesnake grass	1		1	
Poaceae		*Hordeum jubatum*	L.	Fox-tail barley				
Poaceae		*Phleum pretense*	L.	Timothy				
Poaceae		*Poa annua*	L.	Annual bluegrass				
Poaceae		*Poa palustris*	L.	Meadow-grass				
Poaceae		*Poa pratensis*	L.	Kentucky bluegrass				
Poaceae		*Poa trivialis*	L.	Rough-stalked bluegrass			1	1
Poaceae		*Puccinellia distans*	(Jacq.) Parl.	Weeping alkaligrass			1	
Poaceae		*Puccinellia pumila*	(Vasey) A.Hitchc.	Dwarf alkaligrass				
Poaceae	†	*Spartina pectinata*	Link	Freshwater cord grass	1			
Polygonaceae		*Polygonum punctatum*	Ell.	Water-smartweed				
Polygonaceae		*Polygonum convolvulus*	L.	Wild buckwheat				1
Polygonaceae		*Polygonum hydropiper*	L.	Water-pepper				1
Polygonaceae		*Rumex acetosella*	L.	Garden-sorrel				1
Polygonaceae		*Rumex longifolius*	DC.	Dooryard dock				1
Polygonaceae		*Rumex pallidus*	Bigel.	Seabeach-dock				
Polygonaceae	†	*Rumex salicifolius*	J.A. Weinm.	Willow dock		1	1	
Potamogetonaceae		*Potamogeton confervoides*	Reichenb.	Pondweed				
Potamogetonaceae		*Potamogeton epihydrus*	Raf.	Ribbonleaf pondweed			1	1

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Potamogetonaceae		*Potamogeton perfoliatus*	L.	Claspingleaf pondweed			1	1
Potamogetonaceae		*Potamogeton pusillus*	L.	Pondweed				1
Primulaceae		*Lysimachia terrestris*	(L.) BSP	Swamp candle				
Pyrolaceae	†*	*Moneses uniflora*	(L.) A. Gray	One-flowered shinleaf	1			
Pyrolaceae	†*	*Pyrola elliptica*	Nutt. (Shinleaf)	Round-leaved shinleaf		1		
Pyrolaceae	†	*Pyrola secunda*	L.	One-sided wintergreen	1			
Ranunculaceae		*Ranunculus acris*	L.	Tall buttercup		1		1
Ranunculaceae		*Ranunculus cymbalaria*	Pursh	Seashore buttercup		1	2	
Ranunculaceae		*Ranunculus repens*	L.	Creeping buttercup				1
Rosaceae		*Amelanchier bartramiana*	(Tausch) Roemer	Shadbush				
Rosaceae		*Fragaria vesca*	L.	Woodland strawberry			1	
Rosaceae		*Fragaria virginiana*	Duchesne	Strawberry				
Rosaceae		*Potentilla anserine*	L.	Silverweed		1		
Rosaceae		*Potentilla norvegica*	L.	Rough cinquefoil				
Rosaceae		*Potentilla palustris*	(L.) Scop.	Marsh cinquefoil		1		
Rosaceae	†	*Potentilla tridentate*	Ait.	Three-toothed cinquefoil	1	1		
Rosaceae		*Prunus pensylvanica*	L.f.	Pin cherry				
Rosaceae		*Rosa Carolina*	L.	Wild rose		1		
Rosaceae		*Rosa nitida*	Willd.	Swamp rose		1		
Rosaceae		*Rubus acaulis*	Michx.	Northern dwarf-raspberry				
Rosaceae	†	*Rubus chamaemorous*	L.	Bakeapple	1	1		
Rosaceae	†	*Rubus pubescens*	Raf.	Dwarf raspberry		1		
Rosaceae		*Sorbus Americana*	Marshall	American mountain-ash		1		
Rosaceae		*Spiraea alba*	Duroi	Meadowsweet				
Rubiaceae		*Galium tinctorium*	L.	Small bedstraw				
Rubiaceae		*Galium trifidum*	L.	Bedstraw				
Rubiaceae	†	*Galium palustre*	L.	Marsh bedstraw	1			

Table 2 Continued

Family	Status	Species Name	Authority	Common Name	STFX	CBUH	NSPM	ACAD
Ruppicaceae		*Ruppia maritime*	L.	Ditch-grass				
Ruppicaceae	†	*Sanguisorba canadensis*	L.	Canada burnet	1	1		
Salicaceae		*Populus tremuloides*	Michx.	Trembling aspen				
Salicaceae		*Salix discolor*	Muhl.	Pussy-willow				
Santalaceae		*Geocaulon lividum*	(Richards.) Fern.	Northern comandra			1	1
Sarraceniaceae		*Sarracenia purpurea*	L.	Pitcher plant		1		
Saxifragaceae		*Ribes glandulosum*	Grauer	Skunk-currant				
Saxifragaceae		*Ribes hirtellum*	Michx.	Gooseberry		1		
Schizaeaceae		*Schizaea pusilla*	Pursh	Little curlygrass fern				1
Scrophulariace	†	*Euphrasia officinalis*	L.	European eyebright		1		
Scrophulariaceae	†	*Euphrasia randii*	B.L. Robins.	Small eyebright	1	1		
Scrophulariaceae	†	*Melampyrum lineare*	Desr.	Cow-wheat		1		
Scrophulariaceae		*Rhinanthus crista-galli*	L.	Yellow-rattle				
Sparganiaceae		*Sparganium angustifolium var. multipedunculatum*	(Morong) Rydb.	Bur-reed		1	1	1
Sparganiaceae		*Sparganium emersum*	Rehmann	Bur-reed		1	1	
Sparganiaceae	†	*Sparganium eurycarpum*	Engelm	Giant bur-reed	2		1	1
Sparganiaceae		*Sparganium hyperboreum*	Laestad.	Bur-reed			1	1
Sparganiaceae	†	*Sparganium natans*	L. L.	Bur-reed		1	1	
Taxaceae	†*	*Taxus Canadensis*	Marshall	Canada yew		1		
Thelypteridaceae		*Phegopteris connectilis*	(Michx.) Watt.	Long beechfern				1
Thelypteridaceae		*Thelypteris palustris var. pubescens*	(Lawson) Fern.	Eastern marsh fern				1
Typhaceae	~	*Typha latifolia*	L.	Broad-leaved cat-tail				
Violaceae		*Viola adunca*	J.E. Smith	Violet				
Violaceae		*Viola macloskeyi*	F. Lloyd	Small white violet		1		
Viscaceae		*Arceuthobium pusillum*	Peck.	Dwarf mistletoe			1	
Xyridaceae	†	*Xyris Montana*	Ries.	Yellow-eyed grass	1			

Table 3 Rare plants from Scatarie Island. The general location of the collection is given along with GPS co-ordinates and conservation status as given by Nova Scotia Department of Natural Resources (DNR) and the Atlantic Canada Conservation Data Centre (ACCDC). DNR ranks species as red (threatened) yellow (vulnerable) or green (secure). ACCDC ranks species as S1 (extremely rare), S2 (rare), S3 (uncommon), S4 (common) or S5 (abundant).

Species name	Common name	Where found	Collector/ Observer	Date	Herbarium	Latitude	Longitude	DNR Status	ACCDCs Status
Carex rariflora (Wahlenb.) Sm.	Looseflower Alpine Sedge	Howe Point	Williams, M; Currie, N.	10-Aug-95	ACAD	45.993410	59.698470	Red	S1
Cornus. suecica L	Lapland Cornel	Northwest Cove	Ferrier and MacDonald	27-Jun-05	ACAD/CBUH	46.01700500	59.74109700	Yellow	S1S2
		NE of Northwest Cove	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.022238	59.726528		
		3 km N of Northwest Cove	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.031716	59.713684		
		Not Available	Erskine, JS	17-Aug-51	NSPM	46.009932	59.736024		
		Tin Cove	Williams, M	27-Jul-84	NSPM	46.002537	59.732508		
		South of Northeast Harbour	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	22-Jul-53	ACAD	46.015098	59.731938		

Table 3 Continued

Species name	Common name	Where found	Collector/ Observer	Date	Herbarium	Latitude	Longitude	DNR Status	ACCDCs Status
Crassula aquatica (L.) Schoenl.	Water Pygmyweed	Northwest Cove	Erskine, JS	17-Aug-51	NSPM	46.018761	59.731912	Yellow	S2
		Northwest Cove	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.018761	59.731912		
Eleocharis nitida Fernald	Quill Spikerush	S coast	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	22-Jul-53	ACAD	45.999751	59.743593	Green	S3
		S coast	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	22-Jul-53	NSPM	45.999751	59.743593		
Geocaulon lividum (Richardson) Fernald	False Toadflax	Centre of island	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	21-Jul-53	ACAD	46.009932	59.736024	Yellow	S2S3

Table 3 Continued

Species name	**Common name**	**Where found**	**Collector/ Observer**	**Date**	**Herbarium**	**Latitude**	**Longitude**	**DNR Status**	**ACCDCs Status**
Halenia deflexa (Sm.) Griseb.	American Spurred Gentian	Not available	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.009932	59.736024	Yellow	S2S3
Schizaea pusilla Pursh	Little Curlygrass Fern		Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	21-Jul-53	ACAD	46.009932	59.736024	Green	S3
Sparganium hyperboreum Beurling ex Least.	Northern Bur-reed	Northwest Cove	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.018761	59.731912	Yellow	S1S2
			Erskine, JS	17-Aug-51	NSPM	46.018761	59.731912		
Spiranthes romanzoffiana Cham.	Hooded Lady's Tresses	Eastern Harbour	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.033373	59.687777	Green	S3S4

Table 3 Continued

Species name	Common name	Where found	Collector/ Observer	Date	Herbarium	Latitude	Longitude	DNR Status	ACCDCs Status
Stellaria humifusa Rottb.	Saltmarsh Starwort	Northeast Harbour	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.018761	59.731912	Yellow	S2
		Northeast Cove	Erskine, JS	17-Aug-51	NSPM	46.018761	59.731912		
			Williams, M.	27-Jul-84	NSPM		Not Available		
Vaccinium boreale I.V. Hall & Aalders	Northern Blueberry	Near Eastern Harbour	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	21-Jul-53	ACAD	46.033921	59.688941	Red	S2
			Ferrier and MacDonald	27-Jun-05	ACAD/CBUH	Not Available	Not Available		

Table 3 Continued

Species name	Common name	Where found	Collector/ Observer	Date	Herbarium	Latitude	Longitude	DNR Status	ACCDCs Status
Vaccinium uliginosum L.	Bog Blueberry	Northwest Cove	Erskine, JS	17-Aug-51	NSPM	46.018761	59.731912	Yellow	S2
		Centre of island	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	21-Jul-53	NSPM	46.009932	59.736024		
		Northwest Cove	Smith, EC; Schofield, WB; Sampson, DR; Bent, FC	17-Aug-51	ACAD	46.018761	59.731912		
		Northeast Harbour	Smith, EC; Schofield, WB; Taylor, JC; Webster, DH; Slipp, LB	22-Jul-53	ACAD	46.018761	59.731912		
			Ferrier and MacDonald	27-Jun-05	ACAD/CBUH	46.01446568	59.75236424		
			Ferrier and MacDonald	27-Jun-05	ACAD/CBUH	46.01636292	59.74445994		
			Ferrier and MacDonald	27-Jun-05	ACAD/CBUH	46.01670817	59.74342804		

DISCUSSION

Boreal Forest Trees

Much of Scatarie Island is covered by the typical boreal forest found on the Altantic coast of Nova Scotia (Loucks 1961, Davis & Browne 1998). Coniferous species *Abies balsamea* (Balsam Fir), *Picea glauca* (White Spruce) and *Picea mariana* (Black Spruce) dominate the forests. Deciduous hardwoods are less common; of these, *Betula papyrifera* (Paper Birch) and *Betula cordifolia* (Heart-leaved Birch) are frequent, *Sorbus americana* (American Mountain-Ash), *Populus tremuloides* (Trembling Aspen), and *Betula alleghaniensis* (Yellow Birch) are rare. The ground cover is commonly the Schreber's Moss association typical of this forest type (Davis & Browne 1998, Cameron 2004).

Arctic and Alpine Plant Species

Northern plants such as *Cornus suecica* and *Vaccinium uliginosum* are found on Scatarie Island; some colonies are near the extreme southern reaches of the species' range (Roland & Smith 1969, Davis & Brown 1998). These plants are often of interest because they are rare in Nova Scotia and are called the "arctic-alpine flora" (Hounsell & Smith 1966, 1968, Roland & Smith1969, Pronych & Wilson 1993). The surrounding Atlantic Ocean causes the wind, fog and cool temperatures of Scatarie Island and allows these plants to persist south of their typical range. Scatarie Island has cooler summers and warmer winters relative to the rest of Nova Scotia (Cameron 2004). Many of Nova Scotia's rare plants are geographically disjunct populations, perhaps "stranded" here during periods of climate change (Bridgland 1989).

One stand of *C. suecica* was found during our expedition to Scatarie Island. The plants were growing densely with *Juniperus communis* on a cliff headland at Northwest Cove (Table 3). *C. suecica* is an alpine plant and typically occurs in the far north, including Greenland and parts of Eurasia (Roland & Smith 1969, Roland 1998). This plant is known in Nova Scotia only from collections around the Gulf of St. Lawrence, Scatarie Island, and a single record from Queen's County (Roland 1998).

We were able to locate several colonies of Alpine Whortleberry, *Vaccinium uliginosum* (Table 3). *V. uliginosum* is most common in the north between the 60th and 70th parallels, but extends as far south as New Hampshire (Roland 1998). In Nova Scotia this plant persists only where severe wind and exposed mountaintops hinder the growth of other plants (Davis & Browne 1998).

Our expedition found a single specimen of *Prenanthes nana* on a rock outcrop facing a windswept barren. *Prenanthes nana* is found on the cool coastlines of Newfoundland and Labrador and Nova Scotia, and in the mountains of New England and northern New York; elsewhere it is rare (Roland & Smith 1969). It was collected previously by P. Williams (Table 2).

We did not find *Sparganium hyperboreum*, considered rare in Cape Breton (Roland & Smith 1966) and listed as a "yellow" (threatened) species by DNR (2009). *Sparganium hyperboreum* has been previously found growing abundantly in a bog pool at Northwest Cove (Roland & Smith 1966). This plant has a northern distribution, extending from Greenland to Eurasia and the Northwest Territories south to northern Nova Scotia, northern Quebec, Manitoba, and Alberta (Maher et al. 1978, Roland & Smith 1966).

Although *Rubus acaulis* (Arctic Raspberry, Northern Dwarf Raspberry) was not found during our expedition, it was listed previously for Scatarie Island (Godfrey 1971). The species is synonymous with *Rubus arcticus ssp. acaulis* (Michx.) Focke; however, neither species is listed as occurring anywhere in Nova Scotia (Roland 1998, ACCDC 2009). There is no herbarium voucher and therefore this description cannot be verified; future expeditions to Scatarie Island should consider the possibility of its presence.

Two additional plants from Scatarie Island, *Eleocharis nitida* and *Sparganium multipedunculatum*, were listed as rare by Pronych and Wilson (1993). However, both are now listed as secure in the DNR ranking (DNR 2009). *Sparganium multipedunculatum* has been declared synonymous with the more common species *S. angustifolium* (Roland 1998). The Scatarie Island population of *E. nitida* remains a disjunct location from the more abundant populations around the Bay of Fundy (Roland 1998).

Recent archaeological surveys suggest Scatarie Island was settled by Europeans as early as 1715. A 1716 census shows 405 people lived on the island (Chrestien 2001). Occupation of the island continued into the 20th century. There are a few, small, private land holdings on the island where cottages and camps may be found. As a result of this land use history, a number of plant species have been introduced to the island including the Old World species *Radiola linoides,* which in North America is known only from Nova Scotia (Roland 1998). This tiny (3 cm) plant grows near the coast in ditches, roadsides or waste ground. On Scatarie Island, we found this plant growing near *Cornus suecica*, high on a beach at Northwest Cove (Table 3).

CONCLUSION

This checklist is the most comprehensive list available of the vascular plants of Scatarie Island, now including 309 plant species. Our herbarium vouchers expand previous checklists and confirm the observations of previous surveyors (Table 1). Knowledge of the GPS coordinates of rare plants (Table 3) will facilitate further survey efforts necessary for an estimate of the abundance and viability of these populations. More species potentially could be added as well; our expedition added 15 previously unreported species to the island checklist in only four days and therefore the presence of more species is likely. In addition, many of the plant species records are not supported by voucher material (Table 2) and future collecting trips can confirm these records.

Scatarie Island comprises many habitats: exposed barrens, damp bogs, coniferous woods and abandoned homesteads. Its diversity of habitat, isolation from the mainland, and current status as a provincial Wilderness Area make it a compelling location for exploration. This checklist should facilitate future plant surveys attempting to find still more species, augment herbaria collections, track colonies of rare plants or develop a more quantitative description of the vegetation. We hope that this list will encourage further investigation into the ecology of plant populations and communities on Scatarie Island.

Acknowledgements. We thank Robert Cameron for field guidance and Dr. David Garbary and Catherine Sneddon for laboratory assistance. Dr. Dave McCorquodale provided invaluable direction and advice at all stages of this project.

REFERENCES

ACCDC (Atlantic Canada Conservation Data Centre) (2009) List of species occurrence data for Nova Scotia. http://www.accdc.com/products/NCounties.htm. [Accessed 20 June 2009].

Bridgland J (1989) Rare plants in the highlands: key to glacial history. *Conservation* 13(2).

Cameron RP (2004) Resources Guide and Ecological Atlas: for conducting research in Nova Scotia's Wilderness Areas and Nature Reserves. Technical Report 0401, Protected Areas Branch, Nova Scotia Environment and Labour, Halifax, NS.

Chrestien J-P (2001) Archaeologiocal survey and testing of eighteenth-century fishing properties on Scatarie Island (Nova Scotia). Report for the year 2000, Canadian Museum of Civilization, Ottawa, ON.

Davis DS, Browne S (1998) The Natural History of Nova Scotia (2 volumes). Nova Scotia Museum and Nimbus Publishing, Halifax, N.S.

DNR (Department of Natural Resources) (2009) General status ranks of wild species in Nova Scotia. http://www.gov.ns.ca/natr/wildlife/genstatus/specieslist.asp.

Godfrey AP (1971) A trial introduction of willow ptarmigan (*Lagopus lagopus alleni*) to Nova Scotia. MSc thesis, Acadia University, Wolfville, NS.

Hounsell RW, Smith EC (1966) Contributions to the flora of Nova Scotia VIII: Distribution of arctic-alpine and boreal disjuncts. *Rhodora* 68(776):409-418.

Hounsell RW, Smith EC (1968) Contributions to the flora of Nova Scotia IX: Habitat studies of arctic-alpine and boreal disjunct species. *Rhodora* 70(782):176-192.

Loucks OL (1961) A forest classification for the Maritime Provinces. *Proceedings of the Nova Scotian Institute of Science* 25(2):85-167.

Maher RV, White DJ, Argus GW, Keddy PA (1978) The rare and vascular plants of Nova Scotia. Syllogeus No 18, The National Museums of Canada, Ottawa, ON.

Province of Nova Scotia (2006) Scatarie Island Wilderness Area. http://www.gov.ns.ca/enla/protectedareas/wa_scatarie.asp.

Pronych G, Wilson A (1993) Atlas of rare vascular plants in Nova Scotia. Curatorial Report 78, Nova Scotia Museum of Natural History, Halifax, NS.

Roland AE (1998) Roland's Flora of Nova Scotia, 3rd ed. Nimbus Publishing and Nova Scotia Museum, Halifax, NS.

Roland AE, Smith EC (1966) The Flora of Nova Scotia, Part 1. The Pteridophytes, Gymnosperms and Monocotyledons. *Proceedings of the Nova Scotian Institute of Science* 26(2):1-238.

Roland AE, Smith EC (1969) The Flora of Nova Scotia, Part 2. The Dicotyledons. *Proceedings of the Nova Scotian Institute of Science* 26(4):277-743.

Williams P (2000) Scatarie Island vascular plants (unpublished). Retrieved from Atlantic Canada Conservation Data Centre (ACCDC) database by Robert Cameron, 2005.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 69-78

LICHENS OF SCATARIE ISLAND WILDERNESS AREA

ROBERT P. CAMERON[1]*, WOLFGANG MAASS[2]
AND FRANCES ANDERSON[3]
[1]*Nova Scotia Environment*
PO Box 697
Halifax, Nova Scotia B3J 2T8

[2]*71 Windship Lane*
Duncans Cove, Nova Scotia B3V 1K4

[3]*Nova Scotia Museum*
1747 Summer Street
Halifax, Nova Scotia B3H 3A6

In 2001, 2005 and 2007 sixty-one species of lichens were collected from Scatarie Island. Over half the species had a boreal or arctic distribution and slightly less than half had a coastal affinity. New records include five species for Cape Breton of which three species are also new records for Nova Scotia. Cyanolichen diversity is very low for Scatarie Island compared to other coastal collections from Nova Scotia.

En 2001, 2005 et 2007 on a recueilli soixante et une espèces de lichens dans l'île Scatarie. Plus de la moitié de ces espèces avaient une aire de répartition boréale ou arctique, et un peu moins de la moitié étaient des espèces plutôt côtières. Cinq espèces étaient répertoriées pour la première fois au Cap-Breton, trois d'entre elles étant également observées pour la première fois en Nouvelle-Écosse. La diversité des cyanolichens dans l'île Scatarie est très faible comparée à celle d'autres collections recueillies sur les côtes de la Nouvelle-Écosse.

INTRODUCTION

The purpose of this study was to develop a lichen checklist for Scatarie Island as the Island's geographic position, with minimal human disturbance and variety of habitat types suggested the possibility of high lichen diversity. Additionally, although there have been several unpublished vascular plant surveys as well as museum records from the Island, there are no published lichen records or Nova Scotia Museum collections of lichens for Scatarie Island.

Scatarie Island is home to several species of rare vascular plants for Nova Scotia (Cameron 2004); many of these have an arctic or alpine distribution and others include those with a boreal and tem-

---

* Author to whom correspondence should be addressed.
Email: camerorp@gov.ns.ca

perate distribution. Habitats on the island are varied with barrens, wetlands, rocky shores, cliffs and forests all providing a diversity of niches and substrates for lichen colonization.

As Scatarie Island falls within the Atlantic Climate Region there is abundant atmospheric moisture for lichen growth (Davis & Browne 1996). In addition, the Atlantic Ocean provides plants with airborne nutrients from salt spray and large wetlands throughout the island further increase atmospheric moisture.

A lichen is a symbiotic association of a fungus and a photosynthetic microorganism, usually an alga (or occasionally a bacterium). The algae produce carbohydrates by photosynthesis, which are then used by the fungus. In about 10% of the known species of lichens the photosynthesizing partner is a

cyanobacterium in which case it fixes nitrogen and supplies it in organic form to the fungus. The scientific name for the lichen is provided by the name of the fungal partner. Lichens are important pioneers in the initiation and sustenance of ecosystems in otherwise uninhabitable situations. Lichens obtain nutrients through interception of aerosols, particulates, and precipitation (Nash 1996). Water is obtained from the atmosphere or rain, thereby requiring the lichen to remain dormant during times when atmospheric moisture is not available. These same traits of dormancy and nutrient absorption mean lichens tend to grow slowly compared with vascular plants and thus are poor competitors. The ability to remain dormant for long periods and to obtain nutrients through the atmosphere allows lichens to live in harsh conditions. Scatarie Island, with exposed headlands, rocky shores and cool summers, make conditions difficult for vascular plant growth, but ideal for lichens.

METHODS

Extensive collecting occurred between 20 and 25 August, 2001, 8 and 11 August, 2005 and 23 and 24 July, 2007. All fruticose (shrub-like) and foliose (leaf-like) species found were identified in the field or collected for later identification. Some crustose (crust-like) species were identified, but no attempt was made to document all crustose species. Each species was characterized as abundant, common, occasional or rare. Growth form and substrate were also noted. Voucher specimens for twenty-five species were deposited at the Nova Scotia Museum of Natural History (Halifax). Geographic affinity and habitat were taken from Brodo et al. (2001), Gowan and Brodo (1988) and Selva (1999); nomenclature follows Esslinger (1997).

RESULTS AND DISCUSSION

Sixty-one species of lichen were found (Table 1). Of these, 29 were fruticose, 25 were foliose and 7 were crustose growth forms. Forty-two species (69%) were forest dwellers living on the dominant balsam fir which is interspersed with white and black spruce (Cameron 2004). About 25% (13 species) were found in barrens or barren/bog complexes. Six species were found on rocky shores.

Substrate

The greatest number of lichens (48% or 29) were corticolous (living on cortex or bark-like substances). Most species occurred on balsam fir (*Abies balsamea*) followed by white spruce (*Picea glauca*) and black spruce (*Picea mariana*). Few species occurred on birch (*Betula cordifolia*) or mountain ash (*Sorbus americana*) possibly because of the low abundance of these trees on the island.

Six species were found on well rotted deadwood on the forest floor. Of these, only one species, (*Cladonia digitata*), occurs almost exclusively on deadwood (Brodo et al. 2001). The other lignicolous species (inhabitants of wood) occurred on deadwood, but were not restricted to this substrate. All lignicolous species found were in the genus *Cladonia*.

Saxicolous species (inhabitants of rocks) included six species collected from rocky shores and four from inland cliffs and rocky outcrops in barrens.

Fourteen (23%) of the species found were terricolous (living on or in the ground). This community is dominated by species of the genus *Cladonia,* but also includes several species of *Peltigera*. *Peltigera* species grew in forested habitats on damp moss, soil or tree bases while *Cladonia* species tended to be found in barrens, forest openings or disturbed areas along trails. Fruticose *Cladonia* species dominated barrens and hummocks in bogs along with *Cetraria islandica. Cladonia boryi* and *C. terrae-novae* were common on barrens on the island and are probably indicators of these unique coastal barren communities. Although these species can be found in inland barrens they are never abundant.

Biogeography

Phytogeographic affinities of lichens found in this study largely reflect the coastal position of the island. Over half (51%) of the species identified in this study have a boreal/arctic distribution and, in Nova Scotia, are at the southern portion of their range. The number of arctic/alpine vascular plants and high proportion of arctic lichens found here attest to the harsh environmental conditions on the island, which allow these species to survive where the more

Table 1 Lichen species identified on Scatarie Island as well as substrate, abundance and habitat where they were found. Growth form and phyto-geography are summarized from the literature. Phytogeography is for North American distribution.

Species	Growth Form[1]	Substrate	Abundance	Habitat	Phytogeography
Alectoria sarmentosa (Ach.) Ach.	frut.	bark	common	forest	east & west coast
Bryoria trichodes ssp. *trichodes* (Mot.) Brodo & D.Hawksw.	frut.	bark	common	forest	east & west
Bryoria capillaris (Ach.) Brodo & D.Hawksw.	frut.	bark	occasional	forest	east & west
Bryoria fuscescens (Gyelnik) Brodo & D.Hawksw.	frut.	bark	occasional	forest	boreal
Caloplaca sorediata (Vainio) Du Rietz	frut.	rock	occasional	shore	NA
*Cetraria islandica** (L.) Ach.	frut.	soil	locally abundant	barren	boreal/arctic
*Cetraria muricata** (Ach.) Eckfeldt	frut.	soil	rare	barren	boreal/arctic
Cladonia stellaris (Opiz) Brodo	frut.	soil	common	barren, bog forest	temperate, s. boreal
*Cladonia terrae-novae** (Ahti) Hale & Culb.	frut.	soil	common	barren	east coast
Cladonia rangiferina (L.) Nyl.	frut.	soil	common	barren, bog	NA
*Cladonia squamosa** Hoffm.	frut.	soil	occasional	forest	temperate, boreal
Cladonia boryi Tuck.	frut.	soil	common	barren	NE coast
*Cladonia pleurota** (Flörke) Schaerer	frut.	deadwood	occasional		temperate, boreal
*Cladonia maxima** (Asah.) Ahti	frut.	soil	common	forest	east & west coast
*Cladonia cenotea** (Ach.) Schaerer	frut.	deadwood	common	forest	temperate, boreal
*Cladonia scabriuscula** (Delise) Nyl.	frut.	soil	common	forest	temperate, boreal
*Cladonia chlorophaea** (Flörke ex Sommerf.) Sprendel	frut.	deadwood	occasional	forest	NA
Cladonia cristatella Tuck.	frut.	soil	occasional	forest	east
Cladonia strepsilis (Ach.) Grognot.	frut.	soil	occasional	forest	east
*Cladonia digitata** (L.) Hoffm.	frut.	deadwood	occasional	forest	east & west coast
*Cladonia subulata** (L.) F.H. Wigg.	frut.	deadwood	occasional	barren	boreal
Cladonia spp.	frut.	deadwood	occasional	forest	east & west coast
Dibaes baeomyces (L.f.) Rambold & Hertel	frut.	soil	common	barren	east

Table 1 Continued

Species	Growth Form[1]	Substrate	Abundance	Habitat	Phytogeography
Evernia mesomorpha Nyl.	frut.	bark	common	forest	temperate, boreal
Hypogymnia physodes (L.) Nyl.	fol.	bark	abundant	forest	temperate, boreal
*Hypogymnia tubulosa** (Schaerer) Hav.	fol.	bark	common	forest	east & west coast
*Lasallia papulosa** (Ach.) Llano.	fol.	rock	common	barren	east
Lepraria lobificans Nyl.	crust.	bark	common	forest	east & west
Lobaria pulmonaria (L.) Hoffm.	fol.	bark	rare	forest	temperate
Lobaria scrobiculata (Scop.) DC.	fol.	bark	rare	forest	east & west coast
Lopadium disciforme (Flotow) Kullh.	crust.	bark	common	forest	east & west coast
Loxospora elatina (Ach.) A.Massal.	crust.	bark	abundant	forest	boreal
Loxospora ochrophaea (Tuck.) R.C. Harris	crust.	bark	abundant	forest	east
Mycoblastus sanguinarius (L.) Norman	crust.	bark	occasional	forest	boreal
Mycoblastus caesius (Coppins & P. James) Tønsberg	crust.	bark	common	forest	northern
Parmelia sulcata Taylor	fol.	bark	common	forest	northern
Parmelia squarrosa Hale	fol.	bark	abundant	forest	east & west
Peltigera horizontalis (Hudson) Baumg.	fol.	soil	occasional	forest	temperate
Peltigera aphthosa (L.) Willd.	fol.	soil	occasional	forest	temperate, boreal
Pertusaria amara (Ach.) Nyl.	crust.	bark	common	forest	east
Platismatia tuckermanii (Oakes) Culb. & C. Culb.	fol.	bark	common	forest	east
Physcia adscendens (Fr.) H. Olivier	fol.	rock	occasional	shore	NA
Physcia phaea (Tuck.) J. W. Thomson	fol.	rock	occasional	shore	NA
Physcia tenella (Scop.) DC.	fol.	rock	occasional	shore	east & west coast
Platismatia glauca (L.) Culb. & C. Culb.	fol.	bark	abundant	forest	boreal, arctic
*Ramalina roesleri** (Hochst. ex Schaerer) Hue	fol.	bark	common	forest	boreal, arctic coast
*Ramalina farinacea** (L.) Ach.	fol.	bark	occasional	forest	boreal, arctic coast
*Ramalina americana** Hale	fol.	bark	occasional	forest	east
Ramalina thrausta (Ach.) Nyl.	fol.	bark	occasional	forest	boreal coast

Table 1 Continued

Species	Growth Form[1]	Substrate	Abundance	Habitat	Phytogeography
*Ramalina dilacerata** (Hoffm.) Hoffm.	fol.	bark	occasional	forest	boreal
Sphaerophorus fragilis (L.) Pers.	frut.	rock	occasional	barren	arctic
Stereocaulon intermedium (Savicz) H. Magn	frut.	rock	occasional	barren	northeast
*Tuckermannopsis orbata** (Nyl.) M.J. Lai	fol.	bark	occasional	forest	east & west coast
*Tuckermannopsis americana** (Sprengel) Hale	fol.	bark	occasional	forest	boreal
*Umbilicaria muehlenbergii** (Ach.) Tuck.	fol.	rock	occasional	barren	boreal
*Umbilicaria hyperborea** (Ach.) Hoffm.	fol.	rock	common	barren	arctic
*Usnea subfloridana** Stirton	frut.	bark	common	forest	boreal
*Usnea filipendula** Stirton	frut.	bark	abundant	forest	temperate, boreal
Usnea longissima Ach.	frut.	bark	occasional	forest	east & west coast
*Xanthoria parietina** (L.) Th. Fr.	fol.	rock	common	shore	east & west
Xanthoria elegans (Link) Th. Fr.	fol.	rock	common	shore	NA

[1] frut. = fruticose; fol. = foliose; crust. = crustose

* indicates specimen was collected and deposited at the Nova Scotia Museum of Natural History.

temperate species cannot. The Arctic lichen species that tended to occupy barren and bog habitats, often on rocky outcrops, included *Cetraria islandica, Sphaerophorus fragilis* and *Umbilicaria hyperborea*. Boreal distributions were characterized by epiphytes of the genus *Ramalina* and also included epiphytes of the genera *Lopadium, Loxospora* and *Mycoblastus*.

The next most common phytogeographic affinity was represented by those species with a coastal distribution (28 species, 46%). Of these 28 species with coastal distribution, 16 are restricted to eastern North America while the other 12 species have general coastal affinities and can be found on either the west or east coast of North America.

Only 10 species (16%) have a temperate distribution. This group is made up largely of those in the genus *Cladonia*, all of which are terricolous. A few common epiphytes, such as *Evernia mesomorpha* and *Hypogymnia physodes*, are also in this group. Many of the more common temperate species found on the Nova Scotian mainland, such as *Hypogymnia krogiae,* were absent from Scatarie Island. Thirty-three percent of species have a wide Northern American distribution often covering one or more of arctic, boreal, temperate or even subtropical or mountain biomes.

Rarity

Three species, *Cetraria muricata, Cladonia subulata* and *Mycoblastus caesius*, may be new published records for Nova Scotia. *Cetraria muricata* is a terricolous or saxicolous, fruticose species found on the arctic tundra (Brodo et al. 2001). *Cladonia subulata* is a fruticose species found on dead wood on the forest floor. *Cladonia subulata* was rare in Fundy National Park, New Brunswick (Gowan & Brodo 1988). *Mycoblastus caesius* is an inconspicuous epiphytic crustose species and is often overlooked.

Five species may be new published records for Cape Breton. These include those species mentioned above as well as *Bryoria capillaris* and *Lepraria lobificans*. *Bryoria capillaris* is an epiphytic fruticose species found to be most abundant in old growth forests on the mainland of Nova Scotia (Cameron 2002). This species may require the high humidity found in old growth forests, but appears to find the humid forests of Scatarie Island also suitable. Although this is the first published finding of *Leparia lobificans* in Cape Breton, it has been found previously on the Island (Sneddon 1997) and is considered common on mainland Nova Scotia (Cameron 2002).

Several of the species found are considered “ancient forest” species and are relatively uncommon in Nova Scotia (Cameron 2002, Rose 1976, Selva 1994,1999). Included in this group are *Bryoria* *capillaris, Ramalina thrausta,* and *Usnea longissima.* Forests of Scatarie Island are unlikely to be old growth now, but previously there may have been a long continuity of forest cover on the island

Cyanolichens

Cyanolichens (lichens in which a cyanobacterium is one of the symbiotic partners) are excellent bio-indicators as they are sensitive to acid rain, sulphur and nitrous oxide pollution (Richardson 1992). Some cyanolichens are indicators of old growth forests (Rose 1976, Selva 1994) and many are rare in Canada (Goward et al. 1998). Only four species of cyanolichens were found on Scatarie Island, two *Peltigera* and two *Lobaria.* Among the cyanolichen group the genus *Peltigera* is not an old growth forest species and is one of the least sensitive to air pollution. Only one small specimen of *Lobaria pulmonaria* and one of *L. scrobiculata* was found and these had formed only small thalli on a fallen tree.

The low number of epiphytic cyanolichen species on Scatarie Island is remarkable as there are many common epiphytic cyanolichens in Nova Scotia (Cameron & Richardson 2006, Selva 1999, Casselman & Hill 1995). Although Cameron and Richardson (2006) found that epiphytic cyanolichen species richness greatly decreased on coastal headlands, at least a few species were always found including several species in the Gabarus Wilderness Area about 27 km southwest of Scatarie Island. One possible reason for the absence of epiphytic cyanolichens on Scatarie Island may be pollution from the nearby industrial area of Cape Breton.

Isle Haute

The only other small island study of lichens undertaken in Nova Scotia was of Isle Haute (an area of less than 100 ha) in the Bay of Fundy. It is almost 1 degree of latitude south and 5 degrees of longitude west of Scatarie Island. Isle Haute, like Scatarie Island, has mild winters, cool summers, high rainfall and frequent fog. In 1997 the Nova Scotia Museum of Natural History undertook a multi-disciplinary study of Isle Haute in which Karen Casselman collected and identified lichens (Grantham et al. 2000).

The number of lichen species documented for Isle Haute (56) was approximately equal to the number for Scatarie (61) although neither study produced an exhaustive list. Only twelve species overlap both study areas. These include common coastal species of *Ramalina* and *Xanthoria* and very common ubiquitous species such as *Hypogymnia physodes, Parmelia sulcata* and *Parmelia squarrosa.* Isle Haute had a much richer saxicolous lichen flora which may be a result of the basalt bedrock there. However, in our study we made only a few collections from rocks on Scatarie Island.

Absent from Scatarie Island are epiphytes typical of the deciduous trees found on Isle Haute. While Isle Haute had several of the coastal species found on Scatarie Island, Isle Haute did not have the arctic and boreal species common on Scatarie Island.

Acknowledgements. The authors would like to thank David Williams of Protected Areas Branch, Nova Scotia Environment and Labour for organizing the scientific inventory event. We would also like to thank all the scientists and students who participated in the biological inventory with particular thanks to those who accompanied us on our forays, Kathleen Aikens, Jonathan Ferrier, Andrew MacDonald and Dave Harris. Thanks to Stephen Clayden for aid in identifying some of the lichen species.

REFERENCES

Brodo IM, Sharnoff SD, Sharnoff S (2001) Lichens of North America. Yale University Press, New Haven, Conn.

Cameron RP (2002) Habitat associations of epiphytic lichens in managed and unmanaged forest stands in Nova Scotia. *Northeastern Naturalist* 9(1):27-46.

Cameron RP (2004) Resources guide and ecological atlas: for conducting research in Nova Scotia's Wilderness Areas and Nature Reserves. Technical Report 0401, Protected Areas Branch, Nova Scotia Environment and Labour, Halifax, NS.

Cameron RP, Richardson DHS (2006) Occurrence and abundance of epiphytic cyanolichens in Protected Areas of Nova Scotia, Canada. *Opuscula Philolichenum* 3:5-14.

Casselman KL, Hill JM (1995) Lichens as a monitoring tool: a Pictou County (Nova Scotia) perspective. In: Herman TB, Bondrup-Nielsen S, Willison JHM, Munro NWP (eds) Ecosystem monitoring and Protected Areas. Proceedings of the Second International Conference on Science and the Management of Protected Areas, Dalhousie University, Halifax, Nova Scotia, Canada, 16-20 May 1994. Science and the Management of Protected Areas Association, Wolfville, NS, p. 237-244.

Davis DS, Browne S (1996) The natural history of Nova Scotia, 2 vols, rev ed. Nova Scotia Museum and Nimbus Publishing, Halifax, NS.

Esslinger T L (1997) A cumulative checklist for the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada. North Dakota State University, Fargo, North Dakota: http://www.ndsu.nodak.edu/instruct/esslinge/chcklst/chcklst7.htm [first posted 1 December 1997, most recent update 2 March 2004].

Gowan SP, Brodo IM (1988) The lichens of Fundy National Park, New Brunswick, Canada. *The Bryologist* 91(3):255-325.

Goward T, Brodo IM, Clayden SR (1998) Rare lichens in Canada: a review and provisional listing. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.

Grantham RG, Conlin D, Christianson D, Keenlyside D and 7 others (2000) The Nova Scotia Museum Isle Haute Expedition July 1997. Curatorial Report 90, Nova Scotia Museum of Natural History, Halifax, NS.

Nash TH III (1996) Nutrient elemental accumulation and mineral cycling. In: Nash TH (ed) Lichen biology. Cambridge University Press, Cambridge, UK, p. 136-154.

Richardson DHS (1992) Pollution monitoring with lichens. Richmond Publishing, Slough, UK.

Rose F (1976) Lichenological indicators of age and environmental continuity in woodlands. In: Brown DH, Hawkesworth, DL, Baily RH (eds) Systematics Association Special Volume No. 8, Lichenology: progress and problems. Academic Press, London, p. 279-307.

Selva SB (1994) Lichen diversity and stand continuity in the northern hardwoods and spruce-fir forests of northern New England and western New Brunswick. *The Bryologist* 97(3):424-429.

Selva SB (1999) Survey of epiphytic lichens of late successional northern hardwood forests in northern Cape Breton Island. Report to Cape Breton Highlands National Park, Parks Canada, Ottawa, ON.

Sneddon C (1997) Collection number 371L, Nova Scotia Museum of Natural History, Halifax, NS.

NOVA SCOTIAN INSTITUTE OF SCIENCE COUNCIL 2009 – 2010

President: David Richardson
Vice-President: Ron MacKay
Past President: Mary-Jane O'Halloran
Past President: Stuart Grossert
Secretary: Linda Marks
Treasurer: Elaine McCulloch
Editor: Peter G. Wells
Librarian: Sharon Longard
Webmaster: John Cordes
Publicity: Robert Boudreau

Councillors: Robert H. Cook (Writing Competition Coordinator), Charlene MacDonald (NS Science Teachers' Rep), Michelle Paon (2012 Sesquicentennial Committee), Henry (Hank) Bird, Angelica Silva, Doug Strongman

Student Representative: Chris Curry (Dalhousie)

Observers: David Christianson (Nova Scotia Museum), Rebecca (Becky) MacKenzie (Discovery Centre),Tom Sephton (BIO 2012 Anniversary Celebrations Committee), Charlene MacDonald (Science Teachers' representative)

Instructions to Authors

Papers may be submitted in either English or French and should be sent electronically to the editor at (nsis@dal.ca). The title should be followed by names, addresses and E mails of all authors. An abstract of up to 200 words should follow. As appropriate, sections devoted to introduction, methods, results, discussion, conclusions and references should be included. Canadian spelling and SI units should be used wherever possible. There is currently a page charge of $25 per page but this will not be levied if all authors are NSIS members (Membership costs $25 per year for regular members and $10 year for students.) Tables, figures and black and white photographs may be included and will be published without an extra charge. Publication of colour figures in any hard copy of the journal will incur a charge that must be borne by the author and will likely be in the range of $500 per plate which may be a single photo or a collage. All tables and illustrations should have a title and a self-explanatory legend.

Refer to back issues of the Journal for general layout of a paper. Pages should be numbered. References should be in alphabetical order and give the full title of the journal and issue numbers where appropriate, thus:

Nielsen, K.J., & France, D.F. (1995) The influence of adult conspecifics and shore level on recruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine Biology and Ecology* 188 (1):89-98.

Cushing, D. & Walsh J. (1976) The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975) Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

Personal Communication: Smith A.J. (2001, pers. comm.) in text.

Website Citation: Author (year) title, URL and date accessed.

Authors are responsible for correcting and returning proofs promptly. Authors will be provided with a PDF of their paper, free of charge. NSIS members receive a hard copy of the Proceedings as part of their annual membership. Copies of Special Issues of the NSIS proceedings may also be purchased from NSIS at a charge established by the NSIS. See the NSIS website http://www.chebucto.ns.ca/Science/NSIS/ for details.

PROCEEDINGS

of the

Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA

Volume 45 2010 Part 1

CONTENTS

Managing the Scatarie Island Wilderness Area:
Introduction to issues for an island protected area
David Williams and Robert P. Cameron 1

Intertidal invertebrates of Scatarie Island:
A preliminary species inventory and habitat description
K. L. White, S. M. Townsend, A. S. Reynolds and E. B. Barrington 9

Beetles (Coleoptera) of Scatarie Island, Nova Scotia, Canada
Christopher G. Majka Sheena M. Townsend, Kathleen R. Aikens,
Jeffrey Ogden, A. Andrew M. Macdonald and
David B. McCorquodale 18

Freshwater and intertidal fishes of Scatarie Island, Nova Scotia
S. C. Mitchell 35

A checklist of vascular plants from Scatarie Island, Nova Scotia
Jonathan Ferrier, A. Andrew M. Macdonald and Barry R. Taylor 45

Lichens of Scatarie Island Wilderness Area
Robert P. Cameron, Wolfgang Maass and Frances Anderson 69

The Proceedings of the Institute have been published since 1863. Back issues are available from the Institute's library housed in the Killam Library, Dalhousie University, Halifax, and early issues up to 1910 are available on-line at:

http://dalspace.library.dal.ca/dspace/handle/10222/11192

ISSN 0078-2521

NOV
5516
.b

MCZ
LIBRARY
JAN 04 2011
HARVARD
UNIVERSITY

PROCEEDINGS
of the
Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA

ISSN 0078-2521

Volume 45 2010 Part 2

P.G.Wells and D.H.S. Richardson – Editorial 1

A. W. McCulloch
Sir John William Dawson: A Profile of a Nova Scotian Scientist 3

J. W. N. Steenberg and P.N. Duinker
Post-hurricane coniferous regeneration in Point Pleasant Park 26

J. A. Poissant and H. G. Broders
Differentiation of two Myotis species (Chiroptera: Vespertillionidae) at Hayes Cave, Nova Scotia, based on echolocation call characteristics 55

Zoe N Lucas and Lisa J Natanson
Two shark species involved in predation on seals at Sable Island, Nova Scotia, Canada 64

NSIS Student Science Awards 2009-2010
Prize Winning Papers 89

G. R. G. Hutton
Understanding influence of scientific information in the digital age: a study of the grey literature of a United Nations advisory group 91

B. Langer
The Middle Ground. Why we can't save nature for nature? 102

Cont'd on back cover

© Nova Scotian Institute of Science, 2010
Affiliated with Access Copyright, The Canadian Copyright Licensing Agency http://www.accesscopyright.ca

Date of Publication, November 2010

The Proceedings of the Nova Scotian Institute of Science are supported in part by a grant from the Department of Tourism Culture and Heritage, Government of Nova Scotia, with the support of the Nova Scotia Museum. Publication of articles, principally but not exclusively in the area of natural and engineering science, will be considered as well as papers emanating from studies in the health professions. Both regular issues and special issues devoted to topics of current Nova Scotian or Maritime interest are published.

Editorial Board

Peter G. Wells (Dalhousie University)	Editor
David H.S. Richardson (Saint Mary's University)	Associate Editor
Sarah Stevenson (Dalhousie University)	Production Editor
Gail LeBlanc	Layout and Production
Saint Mary's University	Printing
Roby Austin (Saint Mary's University)	Physics
Nola Etkin (UPEI)	Chemistry
Mike Dadswell (Acadia University)	Aquatic Ecology, Fisheries, Tidal Power
David Garbary (St. Francis Xavier University)	Plant Biology
Bruce Hatcher (Cape Breton University)	Marine science
Martha Jones (Cape Breton University)	Estuarine ecology, Invasive Species
Andrew Hamilton-Wright (Mount Allison University)	Artificial Intelligence
Eric Mills (Dalhousie University)	History of Science
Brian Petrie (BIO-DFO)	Oceanography
David W Piper (BIO-NR)	Geology
Martin Willison (Dalhousie University)	Conservation Ecology

Manuscripts should be submitted electronically to the editor (**nsis@dal.ca**). Membership of the NSIS is open to all those interested in Science and subscription details can be found on the Nova Scotian Institute of Science website **http://www.chebucto.ns.ca/Science/NSIS.** Members of the NSIS are not required to pay page charges but others are currently charged $25 per page to help defray the cost of publication **http://www.chebucto.ns.ca/Science/NSIS/index-new.html**

PROCEEDINGS
of the
Nova Scotian Institute of Science
HALIFAX, NOVA SCOTIA

ISSN 0078-2521

Volume 45 2010 Part 2

P.G.Wells and D.H.S. Richardson – Editorial 1

A. W. McCulloch
Sir John William Dawson: A Profile of a Nova Scotian Scientist 3

J. W. N. Steenberg and P.N. Duinker
Post-hurricane coniferous regeneration in Point Pleasant Park 26

J. A. Poissant and H. G. Broders
Differentiation of two Myotis species (Chiroptera: Vespertillionidae) at Hayes Cave, Nova Scotia, based on echolocation call characteristics 55

Zoe N Lucas and Lisa J Natanson
Two shark species involved in predation on seals at Sable Island, Nova Scotia, Canada 64

NSIS Student Science Awards 2009-2010
Prize Winning Papers 89

G. R. G. Hutton
Understanding influence of scientific information in the digital age: a study of the grey literature of a United Nations advisory group 91

B. Langer
The Middle Ground. Why we can't save nature for nature?............... 102

Cont'd on next page

© Nova Scotian Institute of Science, 2010
Affiliated with Access Copyright, The Canadian Copyright Licensing Agency http://www.accesscopyright.ca
Date of Publication, November 2010

PROCEEDINGS
of the
Nova Scotian Institute of Science
HALIFAX, NOVA SCOTIA

Volume 45 2010 Part 2

R.M. Murphy
Waiting for a cure: balancing medicine and quality of life for people living with cancer ... 112

NSIS Reports from Council Officers
(Sessions 2007-2008, 2008-2009, 2009-2010)
President's report, Editors Report, Treasurers Report, Librarians Report ... 125

Inductees to the NS Scientific Hall of Fame
Carlyle Smith Beals 2008
Constance Ida MacFarlane
Margaret Sibella Brown ... 148

The Proceedings of the Institute have been published since 1863. Back issues are available from the Institute's library housed in the Killam Library, Dalhousie University, Halifax, and early issues up to 1910 are available on-line at:

http://dalspace.library.dal.ca/dspace/handle/10222/11192

ISSN 0078-2521

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 1-2

EDITORIAL

Science in the Maritime Provinces and the Role of the Proceedings of the Nova Scotian Institute of Science

The three Maritime Provinces of Canada are blessed with a wealth of universities, research institutes, government departments (provincial and federal), industries and consulting firms dedicated to basic and applied research in many fields. This mass of talented people and state of the art facilities is building upon its international recognition in fields such as marine science, biotechnology, the environmental and health professions, and computer and information sciences, and underpins the region's economic and environmental security. It puts the Maritime Region into a strong position to address looming new challenges requiring a strong knowledge base – climate change, management of living resources, health issues such as cancer and obesity, coastal protection and conservation, pollution control, quality living in urban regions, quality of life balance, and others. A dynamic scientific enterprise, especially one encouraging and employing young scientists in all fields, offers promise of a bright future.

The Nova Scotian Institute of Science (NSIS) is almost 150 years old. It helps to support this enterprise of science serving society through its annual program of seminars, support for young scientists, and the Journal. As you read the pages of the current issue, and access the website of the Society (www.chebucto.ns.ca/Science/NSIS/), please reflect on the role of science in Maritime society, and its latest developments. We would like to hear from you, have you participate in the Society's program, and especially have you contribute to these pages.

The Journal has a new and committed Editorial Board. Its members will help direct the new PNSIS ship on the journey of addressing the scientific and societal challenges of the new century, and reporting our best science. We are building on a proud foundation for the Journal, thanks most recently to the dedicated work of the past Editor, Dr. James (Jim) Stewart.

The NSIS would like to see a diversity of articles in the Proceedings, ranging from papers of original research from across the disciplines, to viewpoint articles, reviews of work in current fields of research, book reviews, and letters to the Editor. An Editorial may even appear from time to time! With your help and input, the Proceedings can continue to be a dynamic outlet for new and important information in Maritime science. Articles are especially encouraged from the natural and engineering sciences, as well as from the health professions, but papers in any of the natural and related social sciences (e.g. history of science, environmental economics, information science and management) of Nova Scotian or Maritime interest will be considered.

The NSIS looks forward to celebrating its 150th Anniversary in 2012, with special issues of the Proceedings planned for that year. Please read the journal, become a contributor, and join in this exciting journey of documenting scientific discovery and progress in Nova Scotia and the Maritimes.

Peter G. Wells, Ph.D., Editor

David H.S. Richardson, Ph.D., Associate Editor and President, NSIS

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 3-25

SIR JOHN WILLIAM DAWSON: A PROFILE OF A NOVA SCOTIAN SCIENTIST

ARCHIBALD W. McCULLOCH
12 Lexington Avenue
Fall River, Nova Scotia

This is a summary of the life and work of Sir John William Dawson (1820-1899), a Nova Scotian who made major contributions to geology, education and the development of science in Canada. His early life and educational work in Nova Scotia, his years as Principal of McGill, his success in developing science, at the community, national, and international level, his prolific written output, and highlights of his geological work are described.

Key words: Darwin; Education; Eozoon; Fossils; McGill; Pictou; Royal Society of Canada; Science and Religion

INTRODUCTION

Much has been written about John William Dawson (known as William Dawson). This paper draws extensively on Sheet-Pyenson's detailed biography (Sheets-Pyenson 1996), and on his autobiography, published posthumously (Dawson 1901), as well as other valuable sources (Adams 1899, Ami 1900, Clark 1971, Collard 1942, Eakins & Sinnamon Eakins 1990, Hook 1990, MacIntosh 1930, O'Brien 1971, Pighetti 1980, Sheets-Pyenson 1998, Vaillancourt 1973, Wood 1991). The first 35 years of his life, based largely in his birthplace of Pictou, established the scientific, educational and administrative skills later brought to his remarkable career in Montreal as Principal of McGill and as a vigorous proponent of science in Canada. The formative years in his native province also established his religious convictions, which were to strongly influence his career. His contributions in geology and paleontology spanned both eras.

NOVA SCOTIA (1820-1855)

Growing up in Pictou

The son of Scottish immigrants, James and Margaret (Rankine) Dawson, William was born in Nova Scotia on 13 October, 1820. When a recession in 1823-24 destroyed his business and placed him in serious debt, James started a printing and publishing business, and vowed to pay his creditors in full. This commitment, shared by the entire family, was to have an impact on William's early career.

Email: archie.mcculloch@ns.sympatico.ca

The Dawsons were devout Christians, and their strong Presbyterianism was a major influence in the home.

William received his schooling at Pictou Academy (1833-1839), where he received a grounding in the scientific and literary basics. Established in 1816 by Thomas McCulloch (Whitelaw 1985), the Academy enjoyed excellent resources, including a well-stocked library, scientific equipment, and McCulloch's own impressive natural history museum.

As a child William was not encouraged to make friendships, and he had a lonely and introspective childhood. The death in 1837 of his only sibling, James, four years younger, had a traumatic impact on William and his parents, and later served to strengthen his sense of duty to his parents (Dawson 1901). His after-school time was spent reading, gardening, fishing and exploring the countryside. Sparked by an innate scientific curiosity and keen interest in the natural history of his environment, he eagerly studied birds, plants, insects, shells, rocks, minerals, and fossils. Thomas McCulloch encouraged his young student in these endeavours. As a teenager Dawson roamed the nearby coalbeds and shale formations, looking for fossils. In summer vacations he went further afield to explore the Joggins area and other locations, employing textbooks such as "Principles of Geology" and "Elements of Geology" by eminent British geologist Charles Lyell (Lyell 1830, 1838) to improve his appreciation of the rocks, minerals and fossils he observed. He quickly accumulated a significant collection, which he developed through specimen exchanges with others. These early surveys left him with not only a great enthusiasm for geology, but also a local reputation as an authority on the subject. At the age of 16, William spoke to the Pictou Literary and Scientific Society (Dunlop 1973) "On the Structure and History of the Earth" - clearly a harbinger of things to come.

Getting Started in Geology

As an 18 year old, William Dawson's first interest was geology, but he had a more immediate role to play in helping maintain his father's business. The family decided, however, that he should attend the University of Edinburgh, where between 1840 and 1841 he studied under John Hutton Balfour (botany), Edward Forbes (paleobotany), William Gregory (chemistry) and Robert Jameson (mineralogy and physical geography). Economic circumstances at home forced him to curtail his studies and return to Pictou in 1841, where his time continued to be divided between the family business and natural history. The forced break in his training was to be fortuitous. In the summer of 1841 in Nova Scotia, Dawson met both Charles Lyell and William Logan, who had just been appointed as Director of the

Geological Survey of Canada. Dawson told Lyell of his own studies and explained his conclusion that Nova Scotia's coal beds belonged to three distinct stratigraphic units. When Lyell returned to Nova Scotia in 1842, he naturally recontacted his "local authority" and together they explored the Pictou coalfields and other geological sites in the province. The unique combination of Lyell's expertise and experience and Dawson's detailed local knowledge not only led to scientific discoveries, but also established a strong and lifelong mentor/protégé relationship between the two men (Collard 1942). Lyell encouraged Dawson's continuing field work in Nova Scotia, and also facilitated publication of his findings. Articles published by the Geological Society of London, starting in 1843, were Dawson's first research publications (Dawson 1843).

Despite this early scientific success, Dawson enrolled in divinity classes in 1844, and considered becoming a minister, a logical calling at the time for a graduate of Pictou Academy, and one for which he had earlier prepared by studying Hebrew. However, the continuing demands of the business and his own expanding geological interests served to make this career path implausible.

Dawson returned to Edinburgh University in 1846 to get additional training in practical chemistry, and to learn microscopic techniques. When he returned to Pictou in 1847 his new skills started to open doors. In 1848 he was contracted by the General Mining Association of London (GMA) to do an evaluation of coal mining in Cape Breton. He also performed assays and evaluations of coal, copper, and iron deposits for the province, as well as fieldwork as a consultant for a number of small mining companies and entrepreneurs (Sheets-Pyenson 1996, Wood 1991).

When he set sail for Halifax in 1847, Dawson did not travel alone. Earlier that year he had married Margaret Mercer, daughter of an Edinburgh lace merchant. The need to maintain a Pictou base to meet his ever present family responsibilities meant that the couple took up residence in the Dawson family home. In the next few years Dawson coordinated his partnership in his father's business, survey work, geological research, some teaching (and preaching), and also completed his first book "A Handbook of the Geology and Natural History of the Province of Nova Scotia", published by James Dawson, and soon used as a standard textbook in Nova Scotian schools (Dawson 1848). He taught natural history courses at Pictou Academy (1848), and gave a course of lectures at Dalhousie College in Halifax (1850). The latter, open to both students and interested members of the public, represented an early attempt at "university extension" (Dawson 1901, Pighetti 1980). While in Halifax he gave a presentation to the Halifax Mechanics' Institute, a precursor organization to what we now recognize as the Nova

Scotian Institute of Science, on the composition of soils, and also performed a number of assays for the Institute's museum.

Nova Scotia's first Superintendent of Education (1850-1853)

The young Dawson impressed George Young, Chair of the Province's education committee, and Joseph Howe, the Provincial Secretary. Anxious to reform the educational system in Nova Scotia, the two men persuaded Dawson to fill the new position of Superintendent of Education. Lyell had warned Dawson to avoid educational work, unless it also guaranteed time for research. Although reluctant to assume the Superintendent role, he did so when Howe pointed out that the position would require travel throughout the province, and that since one planned initiative was the teaching of agriculture in the schools, he would have an excellent excuse to study soil composition. Once in the position, Dawson applied to it his characteristic and remarkable level of commitment and vigour (Hook 1990, Sheets-Pyenson 1996, Vaillancourt 1973, Wood 1991).

In 1850 there was a serious shortage of teachers, and schools typically had poor facilities and supplies. Less than half of Nova Scotian children attended school, and many from poorer families were excluded. As a prelude to his work, which he insisted be based in Pictou, he visited a number of public schools in Canada and the eastern US to examine issues such as teacher training, curricula and funding.

Dawson recommended a humanitarian approach to childhood education as promoted by Scottish Free Church reformer David Stow, as well as a uniform school system, free to all, without class distinction, and under centralized government control. Also high on his list was the need for systematic teacher training.

At the time Dawson attended Pictou Academy, there were two Presbyterian factions – the Secessionists (led by Thomas McCulloch) and the Church of Scotland - each of which fought to control the town's higher education. Frustration over their squabbling led to McCulloch's departure in 1838 to take up the position of Principal of Dalhousie College (Whitelaw, 1985). Having witnessed McCulloch's efforts in Pictou beset by political and religious infighting, Dawson was determined that provincial schools should be non-denominational, and strongly opposed separate schools. While advocating respect for religion in general, he decreed that denominational religious instruction should not be part of the school curriculum.

Recognizing also that acceptance of a 30 year old Superintendent would be difficult for some, he decided "to proceed on the principle that what was well might be left as it was" (Dawson 1901). He gained further community support by holding local meetings to identify and discuss the special needs and issues of each district. He was also required to spend considerable time in Halifax, explaining plans and progress to members of the legislature. His workload was phenomenal. In his first two years he travelled to more than 500 schools, held 56 public meetings, gave 113 lectures, and organized 8 teachers' institutes (Wood 1991). In his autobiography he describes difficult journeys to less accessible parts of the province, such as Brier Island and Advocate Bay (Dawson 1901).

In addition to teachers' institutes, he encouraged formation of teachers' associations, and published a "Journal of Education", distributed to teachers throughout the province. He set out to supply the schools with basic texts on arithmetic, geography, reading, and other subjects, and by the end of 1852 had already distributed 12,541 books and 893 maps (Wood 1991). He also ensured that chemistry, history, agricultural chemistry, and natural history were part of the school curriculum. In his relatively short tenure, Dawson oversaw a number of other improvements, including better teaching methods, recognition of the need for systematic teacher training, better school buildings, school libraries, increased attendance, organized school administration, reliable provincial school statistics, and most importantly, increased public awareness of the value of education.

Central to his educational reform were the creation of a provincial Normal School (teachers' training institute), and provision of free schooling based on compulsory county assessment. He shrewdly used his talent for building consensus to draw broad public support for these ideas. However, his educational model required a major readjustment in public thinking, with its introduction of state authority in an area which had traditionally been under the control of church and family. His proposed School Bill fell victim to political partisanship, and it was not until 1863 that legislation was passed implementing a free school system and compulsory assessment. Looking back at his role as Superintendent, Dawson described it as "that of the pioneer" (Dawson 1901), while Vaillancourt (1973) has described it as that of "educational missionary". Dawson's efforts laid the foundation for a common school system, which better prepared Nova Scotia for the coming period of industrialization (Sheets-Pyenson 1996, Vaillancourt 1973, Wood 1991).

The Superintendent position required him to travel throughout Nova Scotia, and he took advantage of the opportunity to continue his personal geological survey of the province. Some of his most significant scientific discoveries were in fact made while he was most preoccupied with his duties as Superintendent. The superhuman energy and effort which Dawson brought to his "two careers" proved to be unsustainable, and in 1852 he became seriously ill.

He agreed to remain as Superintendent for an additional year, on condition that his duties would be largely administrative. In 1853 Alexander Forrester succeeded him as Superintendent; Forrester was also named as first Principal of the Normal School, opened in Truro in 1855. Dawson viewed the opening of the Normal School as the most important development arising from his own tenure (Sheets-Pyenson 1996).

In accord with the plan to teach agriculture in the schools, Dawson prepared his "Scientific Contributions to Agriculture" (Dawson 1853), and followed this with "Practical Hints to the Farmers of Nova Scotia" (Dawson 1854). The two works were later revised and combined into a single text "First Lessons in Scientific Agriculture for Schools and Private Instruction", later used at McGill Normal School (Dawson 1864).

Major Fossil Finds

In 1852 Charles Lyell returned to Nova Scotia, and he and Dawson explored the interiors of petrified tree trunks discovered in the cliffs at Joggins, a site added to the list of UNESCO World Natural Heritage Sites in 2008. It was during this excursion that the two were to make revolutionary fossil finds, including *Dendrerpeton acadianum* (the earliest reptilian remains then known in North America) and fragments of a shell, belonging to the oldest land snail (*Pupa vetusta*) then known (Dawson & Lyell 1853). These and other similar findings were of major significance to paleontologists, Lyell asserting that they opened a new chapter in North American geology. The dramatic new discoveries and subsequent field work by Dawson represented some of his most important scientific work (Dawson 1863a, 1863b). In 1854 Dawson was awarded his Fellowship in the Geological Society of London. Falcon-Lang and Calder (2005) have described Dawson's work on the coal measures of Nova Scotia as that of "a very modern paleobotanist", as evidenced by his emphasis on field work, skills in microscopic analysis and multidisciplinary approach, linking fossil plant descriptions to geological context. His differentiation of the provincial coalbeds made him "a scientist well ahead of his time" (Falcon-Lang & Calder 2005).

It is astonishing to reflect upon the immense productivity of William Dawson during the early and mid 1850s. He was able to fulfill all the diverse responsibilities of his Superintendent position, conduct and publish geological research, and at the same time write books, including what was perhaps his most significant book: "Acadian Geology" (Dawson 1855). Dedicated to Lyell, this provided a comprehensive description of the geology of Nova Scotia, New Brunswick and Prince Edward Island. The major section of its more than 400 pages comprised five chapters on Carboniferous systems, and an appendix contained a fossil listing. (Revised and expanded editions were published later (Dawson 1868, 1878, 1891)). “Acadian Geology” firmly established Dawson’s reputation as one of the leading geologists of the day.

When his mother died in 1854, Dawson was released from the family ties he felt so keenly, and which had kept him in Pictou. Encouraged by Lyell, he applied in 1854/55 for the position of Chair of Natural History at Edinburgh. Despite numerous testimonials Dawson’s bid was unsuccessful.

During Lyell’s 1852 visit, he had introduced Dawson to Sir Edmund Head, then Lieutenant Governor of New Brunswick, an introduction which led to Dawson’s invitation to join the Ryerson Commission looking at King’s College in Fredericton. When Head later became Governor General of Canada, he also became a Visitor at McGill College. McGill was in desperate need of new leadership, and Head convinced its Board of Governors that Dawson was the man to provide this, meeting all the criteria (that the new Principal be a layman, religious, capable, modern and young) for the position. Waiting in Halifax to travel to Glasgow for a British Association meeting, Dawson not only received news that he did not get the Edinburgh appointment, but also received an unexpected offer to become Principal of McGill.

At the age of 35, Dawson had already established his scientific reputation, had just published a comprehensive treatise on the geology of Eastern Canada, and had amassed considerable practical experience in education, administration, publishing, business and politics, all of which would find good use in Quebec. Although initially reluctant to take a position which would clearly limit his research, he was ready for a change, and in 1855 he left for Montreal with his wife and three young children.

MONTREAL (1855-1899)

Building a University: 38 Years at McGill

When Dawson arrived at McGill he found a few dilapidated buildings, limited equipment, and an institution in precarious financial condition. With three Faculties (Law, Medicine and Arts), there was a total, mostly part-time, teaching staff of 16, and about 80 students. Five years earlier he had thrown his energy and talents at reforming the educational system in Nova Scotia, and he now put body, mind and spirit into working with the Board of Governors to revitalize the university. He again took upon himself an exceptional workload, assuming all of the administrative and other functions of the Principal position as well as lecturing 20 hours per week in chemistry, geology, paleontology, zoology and agriculture. He established a library, and actually served as librarian. He also set up a small museum, which quickly became overcrowded, with much of the working collection accommodated in his home. Examples of Dawson's personal commitment were his purchase of trees and plants to beautify the campus, and the way in which he and wife Margaret opened the doors of their home to students, faculty and visitors; the students referred to such invites as "Tea and Fossils".

In the absence of government support, the fortunes of the university were very dependent on the support of the community – in this case that of Montreal's wealthy anglophone business class. Many of these commercial leaders were of Scottish Presbyterian background. Although Dawson recognized that his total abstinence from alcohol "was not, I fancy, understood or appreciated in Montreal", his heritage and Presbyterianism clearly worked in his favour as he energetically applied himself to soliciting their financial support. Not only did he persuade individuals to provide support to the university, he also took advantage of, and even provoked, competition between the donors. His focus on applied sciences was of particular appeal to many of the benefactors. It is estimated that during his term as Principal he raised a total of more than $6 million in private donations (Sheets-Pyenson 1996).

The support of Montreal's business leaders, such as William Molson, Peter Redpath, and W. C. Macdonald, came in various forms, including new buildings and facilities, endowed Chairs, and acquisition of specimens for the museum. Redpath funded the Peter Redpath Museum of Natural History and the Redpath Library. Sir William Logan led a fundraising effort to establish an endowed Chair in geology, and in 1883 Dawson himself was appointed as the first holder of this (Logan) Chair. As new facilities appeared, civic pride in the University grew, and enrolment increased rapidly.

McGill University represented a small, largely Protestant and English-speaking entity within a French-speaking society dominated by the Roman Catholic Church. Dawson was concerned at the low level of scientific instruction in French schools, and greatly feared the Jesuit influence on education, especially following Confederation. Despite being opposed in principle to the concept of separate schools, he considered that Quebec's system was unavoidable, and worked to maintain Protestant education in the province. He was a member of the Protestant Board of School Commissioners in Montreal, and also served for ten years on the Protestant Section of the Council of Public Instruction in Quebec.

Following his success with the Normal School in Nova Scotia, one of his first steps as Principal was to help establish the McGill Normal School (1856). He was unexpectedly called upon to assume yet more responsibilities as Principal and science teacher at the new Normal School, roles he performed for thirteen years. These additional duties halved the summertime available for research. In 1868, after more than a decade of strenuous administrative and teaching duties at McGill University and Normal School, and with the encouragement of Lyell and Logan, he made an unsuccessful bid for the Principal position at Edinburgh. One positive outcome of this was his release from his duties at the Normal School. Despite all the demands on his time, he was able to prepare a number of university textbooks on geology and zoology (Dawson 1870a, 1871b, 1880a).

At age 70 Dawson was still lecturing up to 14 hours per week. When ill health forced him to retire in 1893, student enrolment was approaching 1000, and there were more than 100 faculty, and more than a dozen buildings on campus. Under his stewardship, McGill had grown from its impoverished state of 1855 to become one of North America's most respected universities.

Higher Education for Women

Dawson was an advocate for higher education of women, and in 1871 he worked with Mrs (John) Molson and several of her friends to establish the Montreal Ladies Educational Association. This operated for 14 years, with Dawson himself teaching its natural history classes. He enjoyed teaching "earnest and attentive young women" (Dawson 1901). At the Association's first session he gave an insightful lecture on the benefits to society of higher education for women; the text is reproduced in his autobiography (Dawson 1901). The Protestant School Board established the Montreal High School for Girls as a feeder school for the University. McGill allowed the School's graduates to be examined for an Associate in Arts, and in 1877 a class of ten passed the examination. In 1884 Sir Donald Alexander Smith provided the funds necessary to admit women to the first two years of the Arts program, in what was referred to as the Donalda Special Course. Smith soon doubled his endowment to allow for extension to the third and fourth year classes, and by the 1887-88 session there were 26 regular and 82 part-time students enrolled; a total of eight women graduated that year.

The Peter Redpath Museum

At the time the new Principal was expanding his own collection, Montreal was the headquarters of the Geological Survey of Canada, which housed the national geological collection. Following Confederation, however, the Geological Survey announced its intention to move to Ottawa. Although Dawson fought hard against the intended move, it finally took place in 1881. He set out to create an even better collection at McGill, and Peter Redpath gave $140,000 to build a new museum, which he wished to be “the best of its kind in Canada”. The Peter Redpath Museum was announced in 1880 in celebration of Dawson’s first 25 years as Principal.

Building Science in Montreal and Canada

In addition to his role as Principal, Dawson set out to stimulate community interest in science, and to position Montreal and Canada on the international scientific map.

The Natural History Society of Montreal (NHSM)

Founded in 1827, and the organization behind the original creation of the Geological Survey of Canada, the NHSM was struggling in 1855. Dawson joined immediately, within the year was elected President, and went on to occupy this position no fewer than 20 times, eventually being elected honorary president for life in 1890. The Society quickly received the full “Dawson treatment”. Subcommittees were formed to streamline activities, and the membership was categorized by discipline (botany, geology, zoology and antiquities). In 1857 the Society took over publication of the “Canadian Naturalist and Geologist”, and later (1888) its successor publication the “Canadian Record of Science”. Publication of its own journal, and its exchange with those of other similar societies, were essential functions of a serious scientific organization at the time (Gibson 1982). Not surprisingly, geology took a central place in both the NHSM and its publications, and Dawson encouraged young Canadian geologists to publish their findings in the journal. He himself contributed more than 170 articles to the Canadian Naturalist and the Canadian Record of Science.

Dawson persuaded the McGill Board to provide a building and other support for the Society, succeeded in obtaining a government operating grant, and encouraged the city’s citizens to become actively involved in the exploration of their environment. In just a few years the Society had become revitalized, and it continued to flourish well into the next decade. The Society’s annual “conversaziones” and field trips became popular civic events. During the 1870s and 1880s the fortunes of the Society appear to have been in synchrony with the time and energy Dawson brought to this end. By the late 1880s attendance at meetings was low, the membership was aging, and very little material was being received for publication. (The Society disbanded in 1925). Following his retirement, Dawson himself no longer regularly attended meetings, although he did read a paper to the Society as late as 1897. Justifiably, the NHSM memorialized him as “the mainstay of the Society for upwards of 40 years” (Sheets-Pyenson 1996).

International Scientific Societies

At Dawson's invitation, the American Association for the Advancement of Science (AAAS) held a meeting in Montreal in 1857. This meeting, hosted by the NHSM, was the first for AAAS to be held outside the U.S., and was attended by scientific leaders from Canada, the U.S. and Britain. Registration was the second largest in the Association's history at that time. In 1881 Dawson was elected President of the AAAS, and a year later the organization met for a second time in Montreal, with the NHSM again acting as host. At the age of 62 (despite the involvement of six special committees) Dawson appears to have "micro-managed" the entire event. This second meeting, with a registration of over 900, was timed to coincide with the grand opening of the Redpath Museum. In 1882 the British Association (BAAS) also announced its intention to hold its annual meeting in Montreal – the first time that this organization had ever met outside Britain. The meeting was very successful, with as many as 2000 at some early sessions; more than 900 British members made the overseas trip, thanks to a generous travel subsidy from the Dominion government. At the opening session of the event, the Governor General formally announced Dawson's knighthood. In 1886 Dawson was elected to preside at the BAAS meeting in Birmingham, England, an event he considered as the greatest honour of his life (Dawson 1901).

Dawson in 1888 also had a vision of a new association of geologists from throughout the British Empire, but this initiative did not come to fruition. With some reluctance, he joined the new Geological Society of America (GSA) in 1889. The GSA met jointly with the AAAS in Toronto in 1890, and Dawson served as GSA President in 1893.

The Royal Society of Canada

The Marquis of Lorne (then Governor General) discussed with Dawson the need for a national scientific organization in Canada; the Governor General himself favoured a broadly based learned society. At meetings held in Dawson's home and later at Government House in Ottawa, a constitution for the Royal Society of Canada (RSC) was drafted. At the inaugural meeting in Ottawa in May, 1882, Dawson was acclaimed as first President of the Society. During his presidential address, he reflected on the enormous progress of Canadian science in the previous four decades, but made pleas for government funding of research and for greater uniformity in education across the country. He commented on the importance of national meetings, especially for those in remote areas, and of a recognized Society journal, which would publish good articles from any source, and thus help younger scientists establish their reputations. Dawson stressed that the Society "must be exclusive in its membership, but inclusive in that it offers benefits to all" (Dawson 1883a).

Fittingly, in 1891, the NHSM invited the RSC to hold its annual meeting in Montreal – the first such meeting to be held outside Ottawa. The 1982 Centenary Medal of the RSC depicts the Marquis of Lorne, William Dawson and Pierre-Joseph-Olivier Chauveau, who succeeded Dawson as President. In 1985, the RSC established the Sir John William Dawson Medal, for important contributions of knowledge in multiple domains.

Geology: Contributions and Controversies

William Dawson's primary expertise was paleontology, and particularly paleobotany. He brought two significant qualities to this lifelong interest – a passionate belief in the value of field work, and the application of microscopic techniques. The latter permitted his identification of 125 new species of Paleozoic plants. He published more than 100 papers on paleobotany, as well as about 50 and 30 on invertebrate and vertebrate paleontology, respectively. In 1859 he described *Psilophyton*, the earliest land plant then known, which he discovered in Devonian strata on the Gaspé peninsula (Dawson 1859). This paper, and his descriptions of Devonian and Upper Silurian formations of Canada, published by the Geological Survey (Dawson 1871a, 1882a), are considered key contributions. His studies resulted in a doubling of known Devonian flora.

He produced a series of articles and a book on amphibian and reptilian species ("Air Breathers of the Coal Period") (Dawson 1863a, b). Many of these discoveries are described in his later book "Some Salient Points in the Science of the Earth" (Dawson 1893a), and his last major paper on this topic was published in 1894 (Dawson 1894a). Despite his strong lifelong opposition to Darwin's theory of natural selection in evolution (see below), Dawson's studies of fossil reptiles and amphibians were to provide important scientific information on vertebrate evolution.

He began a study for the Geological Survey of Cretaceous and Tertiary fossil plants from Western Canada; this yielded several papers, most of which were published in the *Transactions* of the newly created RSC (e.g., Dawson 1883b). He gave an account of his extensive geological studies across Canada in a series of lectures delivered to Boston's Lowell Institute in 1887, and later published as "Geological History of Plants" (Dawson 1888a). This volume, issued as part of a significant international series, was used as a textbook for decades after.

Summers provided him with the only opportunity for extended field work. He returned several times to Nova Scotia and explored other sites in the Maritimes and the eastern U.S. He built a summer home at Little Métis, Quebec, a location which allowed him to collect fossil specimens from Pleistocene and Paleozoic deposits in that area.

William Dawson's half-century of research covered many parts of Canada and virtually all aspects of geology. The subjects of his groundbreaking paleobotany work spanned from the earliest land plants to the Holocene (Falcon-Lang & Calder 2005). He accumulated a huge quantity of new geological information, which resulted not only in the production of an average of ten scientific papers a year, but also his best remembered "Acadian Geology", which laid a framework for subsequent geological work in Nova Scotia, and the later "Geological History of Plants".

Eozoon

Dawson's name is often most closely associated with "*Eozoon*", and the controversy surrounding it. In 1858 an unusual specimen was collected by the GSC in the Laurentians, in some of the world's oldest pre-Cambrian rocks. The samples were characterized by alternating concentric rings of siliceous and calcareous material, and had a fossil-like appearance. Asked by William Logan in 1864 to examine the material, Dawson concluded that the specimen represented organic remains of a giant foraminifer which he named *Eozoon canadense* (see Dawson 1874). Since metamorphic rocks had long been supposed to be free of fossils, this exciting report caught international attention. Other experts agreed that the specimen was of animal origin, and Dawson was convinced that this discovery was of immense geological significance. Controversy erupted in 1866 when two Irish mineralogists claimed that the specimen was inorganic (King & Rowney 1866). Similar samples were collected in Europe and the controversy deepened. Dawson's book "Dawn of Life", published in 1875 and dedicated to William Logan, emphasized the importance of *Eozoon* (Dawson 1875a). Evidence mounted that the specimen was mineral in nature, especially from work by Karl Mobius, a recognized expert on foraminifers (Mobius 1876, 1879). In 1894 *Eozoon*-like specimens were collected from limestone ejections near Mount Vesuvius. These strongly supported the theory that *Eozoon* had been produced by metamorphism of limestone under extreme conditions of heat and pressure. Eventually Dawson alone defended the organic nature of the specimen. His last book "Relics of Life" still included a discussion of *Eozoon* (Dawson 1897), and he was preparing a paper on the topic at the time of his death. A full account of the *Eozoon* story is given in O'Brien (1970, 1971).

Theory of Glaciation

Geographic considerations led Dawson to extensive field work on glacial deposits and fossils in the Montreal area, Maine, the Gaspé peninsula and the Lower St. Lawrence River. He published detailed descriptions of Ice Age fossil flora and fauna in his “Notes on the Post-Pliocene Geology of Canada”(Dawson 1872a), and his later “Canadian Ice Age” (Dawson 1893b). Dawson rejected the hypothesis first raised by Louis Agassiz in 1840 that the Earth had been sculpted by land glaciers, and subscribed to the theory that this was due to the action of giant floating icebergs. Dawson promoted his glaciation position in several articles for the Canadian Naturalist in the late 1850s, and at meetings of the NHSM and the BAAS. New evidence mounted in support of the land glacier hypothesis, including work at the Geological Survey of Ohio (Newberry 1869). While Lyell was very impressed by the second expanded edition of “Acadian Geology” (Dawson 1868), he was critical of the views on glaciation it contained. Throughout the 1880s, however, Dawson held fast to his position (O’Brien 1971).

Bakerian Lecture to the Royal Society

Dawson delivered the 1870 Bakerian Lecture to the Royal Society of London on “Precarboniferous Flora of Northeastern America”. Traditionally, the actual presentation had been followed by its publication in the Society’s *Philosophical Transactions*. Dawson was very anxious to publish in full his work on Devonian plants, which he described as his *magnum opus*. When the Society declined to publish Dawson’s material, choosing to issue only an abstract (Dawson 1870b), he was bitterly disappointed at what he perceived as a personal rejection (Dawson 1901). The material was later published by the GSC (Dawson 1871a, 1882a), and the most important findings were also included in “Geological History of Plants” (Dawson 1888a). Sheets-Pyenson has explained the rejection in the context of the communication difficulties faced by colonial scientists at that time, as well as the economic changes being imposed on long-established societies (Sheet-Pyenson 1991).

Science and Religion

Following this setback by the Royal Society of London, Dawson appears to have lost some of his enthusiasm for scientific studies. In the 1870s and 1880s his speeches and books and prolific writing for literary and religious periodicals reflected a gradually increasing focus on religion. Dawson’s basic belief was that God’s will was revealed both in nature (the Work) and in Scripture (the Word). Exploring nature was akin to reading the Bible, and it was the responsibility of the scientist to relate observations to the teachings of the Scripture. His lifelong objective was to synthesize the two theologies (natural and revealed). O'Brien has provided a full discussion of how the two theologies approach broke down after Darwin's "Origin of Species" and how this led Dawson inevitably to controversy (O'Brien 1971).

Evolution

In 1859 Charles Darwin published his "Origin of Species" (Darwin 1859), presenting his theory of evolution through natural selection. With unquestioning belief in the existence of God, creation and revelation, Dawson rejected Darwin's new hypothesis, citing false methodology and poor reasoning (Dawson 1860a). He insisted that Darwin and his supporters had no evidence, and argued that paleontology did not support evolution through natural selection. Although Darwin's ideas were initially also treated with scepticism by others, they gradually won acceptance by the scientific community in the latter half of the 19th century. Dawson's vigorous anti-Darwinian stance was, however, to continue for the rest of his life. His opposition to Darwinian evolution began to isolate him from the scientific community, and many were critical of his increasingly evangelical approach. Even lifelong mentor Lyell cautioned him, pleading with him to consider phenomena which could now be explained by Darwin's theory. Dawson argued that its acceptance would "rob me of all I value most in this life and that which is to come" (Sheets-Pyenson 1996). Dawson's obituary included in the address by the President of the Nova Scotian Institute of Science (McKay 1903) describes him as "a most uncompromising opponent" of the theory of evolution. Ironically, it was Charles Darwin who co-sponsored William Dawson's Fellowship in the Royal Society in 1862.

Popular Writings

Although he had written most of it in 1855, it was not until 1860 that Dawson published "Archaia", or "Studies of the Cosmogony and Natural History of the Hebrew Scriptures" (Dawson 1860b), in which he combined his scientific expertise and detailed knowledge of Scripture in his first major attempt to reconcile science and Scripture.

In the early 1870s Dawson produced a series of articles on the geological history of the Earth ("free from the taint of agnosticism") for the Religious Tract Society's "Leisure Hour" (UK), and for the similar "Princeton Review". His 1872 book "Story of the Earth and Man" was a compendium of his Leisure Hour articles, and proved to be very popular (Dawson 1872b). As Dawson became increasingly recognized as a strong defender of Christianity, he received invitations from theological and church groups to present public lectures on science and the Bible in Canada and the US. A popular book "Nature and the Bible" (Dawson 1875b) was based on a Christmas lecture series given to New York's Union Theological Seminary. Dawson followed this with a revised version of "Archaia" entitled "Origin of the World, According to Revelation and Science" (Dawson 1877), which sold 1500 copies in the first year, and went through six editions by 1893. His editors encouraged him to popularize his books by using less scientific language. His prodigious written output continued with "The Chain of Life in Geological Time" (Dawson 1880b), "Facts and Fancies in Modern Science" (Dawson 1882b) and "The Meeting Place of Geology and History" (Dawson 1894b). As late as 1896 a course of lectures at the Lowell Institute was presented in book form as "Relics of Primeval Life" (Dawson 1897). Overall, he devoted more than 100 articles and a dozen popular books to promote his views on science and religion, gaining him wide public recognition.

Dawson's combination of science and religious beliefs was very appealing to some, and in 1878 he was offered, but declined, the Chair of Paleontology and Geology at Princeton, a move strongly supported by the Princeton Theological Seminary. Princeton was closely affiliated with the U.S. Presbyterian Church, and Dawson's established geological reputation and anti-Darwinian stance made him an ideal candidate.

Anthropology

In 1860, during some excavations in Montreal, workers uncovered bones and other artefacts of an Aboriginal settlement, and Dawson himself coordinated a controlled recovery at the site. He speculated that the remains were from the early 16th century, and represented the original Indian village of Hochelaga (Dawson 1860c). He wrote several articles for Leisure Hour on prehistoric man, which were combined in the release of his "Fossil Men and their Modern Representatives"(Dawson 1880c), a book of which he was especially proud. Dawson took a leave of absence from McGill from fall 1882 until spring 1884, to tour the Middle East, a project subsidized by a gift of $5000 from his Montreal friends and colleagues. The trip was to result in several geological and anthropological publications, as well as two books - "Egypt and Syria" (Dawson 1885), and "Modern Science in Bible Lands (Dawson 1888b). Trigger has described Dawson's approach to anthropology in the context of his deep religious beliefs and opposition to biological and cultural evolution (Trigger 1966).

DAWSON THE MAN

William Dawson was a paradoxical character. Clearly a competent scientist technically, with good practical skills and powers of observation and deduction, his approach was qualified by his unbending adherence to his religious beliefs. While possessing ample powers of persuasion, as demonstrated in his dealings with school commissioners in Nova Scotia, wealthy business people in Montreal or with leaders of international scientific organizations, he nevertheless showed an uncompromising approach to particular issues. In 1875 Dawson eulogized Charles Lyell as "free from that common failing of men of science which causes them to cling with such tenacity to opinions once formed, even in the face of the strongest evidence" (Dawson 1901, p55) - a characteristic that he found hard to emulate. Despite his autobiographical claim "to have striven – to follow a quiet middle course", the evidence suggests that he may have enjoyed the controversy raised by his uncompromising views.

Sir John William Dawson died on 19th November, 1899 in Montreal, and is interred in that city's Mount Royal Cemetery.

His many accomplishments as a scientist, teacher, administrator, and organizer were recognized during his lifetime. He was awarded his fellowship in the Royal Society of London as early as 1862. The 1880s in particular saw a stream of recognition, including the award of the Lyell Medal for outstanding achievement in geology, being the first appointee to the Logan Chair of Geology, being the only person ever to serve as President of both the AAAS and the BAAS, an honourary LLD from his alma mater (1884), his knighthood, and serving as the first President of the RSC. The mineral dawsonite and Montreal's current Dawson College commemorate his name.

One section of the Redpath Library at McGill is also named in his honour – the Dawson Zoology Library.

Family

In 1849 William and Margaret Dawson's second son, George Mercer, was born less than one month after the tragic death of their first child, James, in infancy. Although childhood illness left George with severe physical handicaps, he performed exceptionally as a student at The Royal School of Mines in London. He joined the Geological Survey of Canada in 1875, and became its Director in 1895. He was a brilliant field geologist and a pioneer in Canadian anthropology. References to "Little Doc", some of his explorations, and the impact of "Elder" Dawson's views can be found in Robertson's recent biography of J.B. Tyrrell (Robertson 2007). The life and work of George Mercer Dawson are described in his memoirs "Beneath My Feet" (Jenkins & Dawson 2007). William and Margaret Dawson had four other children (Anna, William, Eva and Rankine). Anna (b 1851) worked as her father's secretary and also prepared illustrations for his presentations and publications. The younger William (b 1854) was an engineer who became the Director of the Dominion Survey of Tides and Currents (Sheets-Pyenson 1996).

Friends, Mentors and Promoters

Dawson forged lasting relationships with a small number of professional colleagues, including Lyell, Logan, John Jeremiah Bigsby (British paleobotanist), James Hall (New York paleontologist) and Daniel Wilson (who came from Edinburgh in 1853 and was appointed President of the University of Toronto in 1887). Like Lyell, Bigsby had a paternalistic relationship with Dawson. Bigsby was even more dogmatic in his opposition to Darwin, and it was he who was responsible for recruiting Dawson as a contributor to Leisure Hour. Dawson and James Hall met in 1856 and continued to exchange geological specimens for the next four decades. His relationship with Daniel Wilson commenced with their interest in anthropology, and evolved with shared problems as University heads, and as co-workers on creation of the RSC.

In his recent book, "The Outliers", Gladwell speculates that native talent and ability alone were often not sufficient to have assured the success of many eminently successful people (Gladwell 2008). William Dawson possessed the essential intellect and scientific skills, but clearly also benefited from advantages accruing from family, friends, and mentors. These include James Dawson who, despite economic hardship, ensured that his son received advanced schooling, including training overseas; Thomas McCulloch, who as headmaster encouraged his early geological pursuits; Charles Lyell who provided collaboration, mentorship and advice; George Young and Joseph Howe, who recognized his abilities and placed a young man in an important educational reform role; and Edmund Head, who recognized his potential as an educational leader and played a major part in securing his appointment as McGill Principal. Connections and encouragement notwithstanding, Dawson's energy, commitment and vision certainly contributed to his success and many accomplishments.

CONCLUSION

As a scientist William Dawson made enormous contributions to the growth of geology and paleontology. As an educator he initiated important policies and reforms in the school system in his native province, and also provided outstanding leadership to develop McGill as a leading North American university. Although his intransigent positions on some issues and scientific topics, especially evolution, caused some loss of reputation, this is far outweighed by his many positive accomplishments. He was the foremost Canadian scientist and educator of his day, and there is no doubt that his life's work contributed significantly to laying a solid foundation for Canadian geological science in the 20th century. Writing of his former headmaster Thomas McCulloch, Dawson described him as "a man of independent character, confident in himself and in his power of leading others, astute in guiding and regulating affairs, and a keen and incisive controversialist" (Dawson 1901, p 25). In 1899 these words would have been a fitting epitaph for Sir John William Dawson himself, save for some acknowledgment of his pioneering geological contributions.

REFERENCES

Adams FD (1899) Memoir of Sir J. William Dawson. *Bulletin of the Geological Society of America* 11:550-557.

Ami HM (1900) A Brief Biographical Sketch of Sir John William Dawson. *American Geologist* 26:1-48.

Clark TH (1971) John William Dawson. In: Gillespie, CC (ed), Dictionary of Scientific Biography, CC Gillespie (ed), Charles Scribner's Sons, New York Vol. III p. 607-609.

Collard EA (1942) Lyell and Dawson: A Centenary. *Dalhousie Review* 22:133-144.

Darwin C (1859) On the Origin of Species by Means of Natural Selection. Harvard Univ Press, Cambridge MA.

Dawson JW (1843) On the Lower Carboniferous Formation of Nova Scotia. *Proceedings of the Geological Society of London* 4:272-281.

At Northwest Cove, dune grass, *Elymus mollis*, beach grass, *Ammophila brevigulata,* and rose, *Rosa* sp. were swept. Trailside vegetation was swept including alders (*Alnus viridis* (Villars) Lamb. and *A. incana* (L.) Moench), grasses, buttercups, and many Asteraceae (e.g. *Solidago* spp., *Aster* spp.). An inland barren southwest of Savage Cove, the headland above Tin Cove, and backshore vegetation at Savage Cove were swept. Beetles were hand collected from mushrooms (Basidiomycetes), a Leach's Storm-petrel, *Oceanodroma leucorhoa* (Vieillot) burrow, and beach wrack. Small rocks and sand underneath the wrack were sifted for beetles.

All specimens are now in the collections of Nova Scotia Department of Natural Resources, Shubenacadie, Nova Scotia Museum, Halifax, or Cape Breton University, Sydney, Nova Scotia.

RESULTS

Ninety-one species of Coleoptera (290 specimens in 26 families) were collected on Scatarie Island, Cape Breton County, Nova Scotia, 8-11 August 2005 and 14-17 July 2006 (Table 1), bringing the total species documented for the island to 94; 81 native species and 13 introduced species. Three species previously collected on Scatarie Island were not found during this collecting programme. Seventeen species are recorded for the first time from Cape Breton Island. Five of these, *Atheta remulsa* Casey, *Baeocera youngi* (Cornell), *Cyphon confusus* Brown, *Scirtes tibialis* Guérin-Méneville, and *Trixagus carinicollis* (Schaeffer) are recorded for the first time in Nova Scotia and one species, *Hyperaspis brunnescens* (Dobzhansky), was recorded for the first time in Canada (Majka et al. 2007a).

Table 1 Species of Coleoptera collected on Scatarie Island, Nova Scotia

Carabidae
Sphaeroderus c. canadensis Chaudoir – 1
Bembidion scopulinum (Kirby) – 2
† *Bembidion tetracolum* Say – 1
Bembidion transversale Dejean – 5
Pterostichus coracinus (Newman) – 3
† * *Amara communis* (Panzer) – 2
Pseudamara arenaria (LeConte) – 1
Harpalus fulvilabris Mannerheim – 1
Calathus ingratus Dejean – 1

Gyrinidae
Gyrinus affinis Aubé – 1
Gyrinus cavatus Atton – 5
Gyrinus sayi Aubé – 22

Haliplidae
Haliplus immaculicollis Harris – 1

Dytiscidae
Hydroporus signatus Mannerheim – 1
Hygrotus impressopunctatus (Schaller) – 3
Hygrotus sayi Balfour-Brown – 9
Neoporus undulatus (Say) – 20
Agabus inscriptus (Crotch) – 1
Ilybius angustior (Gyllenhal) – 1
Ilybius biguttulus (Germar) – 9
Rhantus wallisi Hatch – 3
Acilius semisulcatus Aubé – 1

Table 1 *Continued*

Hydrophilidae
Anacaena limbata (Fabricius) – 2
Hydrobius fuscipes (Linnaeus) – 1
Cercyon litoralis (Gyllenhal) – 13

Histeridae
Hypocaccus fraternus (Say) – 2

Staphylinidae
† *Tachyporus dispar* (Paykull) – 1
Lordithon scutellaris Campbell – 1
† * *Aleochara (Xenochara) fumata* Gravenhorst – 1
Aleochara (Emplenota) litoralis (Mäklin) – 2
† * *Gyrophaena affinis* Mannerheim – 1
** *Atheta remulsa* Casey – 3
* *Atheta (Datomicra) acadiensis* Klimaszewski & Majka – 8
Atheta (Microdota) pennsylvanica Bernhauer – 1
** *Baeocera youngi* (Cornell) – 1
Creophilus maxillosus villosus (Gravenhorst) – 1
† *Tasgius ater* (Gravenhorst) – 2
Gabrius picipennis (Mäklin) – 5
† *Philonthus politus* (Linnaeus) – 2

Anthicidae
Anthicus scabriceps LeConte – 3

Scarabaeidae
* *Aegialia lacustris* LeConte – 1
† *Calamosternus granarius* (Linnaeus) – 1
Diplotaxis tristis Kirby – 1

Scirtidae
** *Cyphon confusus* Brown – 1
Cyphon variabilis Thunberg – 13
** *Scirtes tibialis* Guérin-Méneville – 1

Buprestidae
Agrilus pensus Horn – 1

Throscidae
** *Trixagus carinicollis* (Schaeffer) – 1

Elateridae
Agriotes fucosus (LeConte) – 1
Agriotes limosus (LeConte) – 1
Dalopius vagus Brown – 8
Athous rufifrons (Randall) – 1
Liotrichus falsificia (LeConte) – 1
Pseudanostirus triundulatus (Randall) – 1
* *Negastrius delumbis* (Horn) – 2

Lycidae
Plateros lictor (Newman) – 1

Cantharidae
Rhagonycha m. mollis Fall – 1
Rhagonycha nanula (LeConte) – 8
Rhagonycha scitula (Say) – 11
Malthodes species – 1

Trogossitidae
* *Thymalus marginicollis* Chevrolat – 1

Phalacridae
Olibrus semistriatus LeConte – 2

Cryptophagidae
* *Atomaria* fuscata Schönherr– 3
* *Atomaria testacea* Stephens – 1

Coccinellidae
*** *Hyperaspis brunnescens* (Dobzhansky) – 1
Anisosticta bitriangularis (Say) – 1

Lathridiidae
Corticarina cavicollis (Mannerheim) – 4

Tenebrionidae
Isomira quadristriata (Couper) – 1

Scraptidae
Anaspis rufa Say – 9

Cerambycidae
Lepturobosca chrysocoma (Kirby) – 1
Xylotrechus undulatus (Say) – 2
Monochamus s. scutellatus (Say) – 1

Eakins PR, Sinnamon-Eakins J (1990) Biographical Note on William Dawson. Dictionary of Canadian Biography 12:230-237 University of Toronto Press.

Falcon-Lang HJ, Calder JH (2005) Sir William Dawson (1820-1899): a very modern palaeobotanist. *Atlantic Geology* 41:2, 103-114.

Gibson SS (1982) Scientific societies and exchange: a facet of the history of scientific communication. *Journal of Library History Philosophy and Comparative Librarianship* 17:144-163.

Gladwell M (2008) Outliers: The Story of Success. Little Brown & Co., Boston, MA.

Hook EL (1990) Sir William Dawson and Henry Marshall Tory. The Achievements and Ideological Attitudes of Two Great Canadian Educators. M.A. Thesis, Carleton University, Ottawa.

Jenkins P with Dawson GM (2007) Beneath My Feet: Memoirs of George Mercer Dawson. McLelland & Stewart, Toronto.

Lyell C (1830) Principles of Geology. John Murray. London.

Lyell C (1838) Elements of Geology. John Murray, London.

King W, Rowney, TR (1866) On the So-called Eozoonal Rock. *Quarterly Journal of the Geological Society of London* 22:185-218.

MacIntosh FC (1930) Some Nova Scotia Scientists. *Dalhousie Review* 10:199-213.

McKay A (1903) President's address, Nova Scotian Institute of Science. *Proceedings & Transactions of the Nova Scotian Institute of Science* (1989-1902), Vol X, p xxxvi.

Mobius, KA (1876) Professor Mobius on the Eozoon Question. *Nature* 20:272-275, 297-301.

Mobius KA (1879) Principal J.W Dawson's Criticism of my Memoir on the Structure of Eozoon canadense compared with that of Foraminifera. *American Journal of Science*, ser 3, 18:177-185.

Newberry JS (1869) Report of Geological Survey of Ohio for 1869, pp 28-33, Columbus, 1871.

O'Brien (1970) *Eozoon canadense*, the Dawn Animal of Canada. *Isis* 61:206-223.

O'Brien CF (1971) Sir William Dawson: A Life in Science and Religion. *Memoirs of the American Philosophical Society*, Philadelphia.

Pighetti C (1980) William Dawson and Scientific Education. *Dalhousie Review* 60:622-623.

Robertson H (2007) Measuring Mother Earth. McClelland and Stewart, Toronto.

Sheets-Pyenson S (1991) Pearls Before Swine: Sir William Dawson's Bakerian Lecture of 1870. *Notes and Records. Royal Society of London*, 45:177-191.

Sheets-Pyenson S (1996) John William Dawson. Faith, Hope and Science. McGill-Queen's University Press.

Sheets-Pyenson S (1998) John William Dawson: Geologist and Educator. *GSA Today* Sept:14-15.

Trigger BG (1966) Sir John William Dawson: A Faithful Anthropologist. *Anthropologica* 8:351-359.

Vaillancourt JP (1973) John William Dawson: Educational Missionary in Nova Scotia. M.A. Thesis, Dalhousie University.

Whitelaw M (1985) Thomas McCulloch: His Life and Times. Nova Scotia Museum, Halifax.

Wood BA (1991) God, Science and Schooling: John William Dawson's Pictou Years 1820-1855. Nova Scotia Teachers' College, Truro. NS.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 1, pp. 26-54

POST-HURRICANE CONIFEROUS REGENERATION IN POINT PLEASANT PARK

JAMES W N STEENBERG* and PETER N DUINKER
School for Resource and Environmental Studies
Dalhousie University, Faculty of Management
6100 University Ave, Suite 5010
Halifax, NS, B3H 3J5

Point Pleasant Park in Halifax, Nova Scotia, sustained catastrophic forest disturbance from Hurricane Juan in September, 2003. This study assessed the adequacy of natural coniferous regeneration in the park in the fall/winter of 2006-2007 and compared the regeneration with pre- and post-disturbance park surveys. The park was stratified using existing trails, transects were spaced 10 m apart, and 20 m2 plots were laid every 10 m. There was a large observed variation of seedling density, with the highest densities being found in the northern and western section of the sample area, and the lowest being found in the south-east. Red spruce was the dominant regenerating species. Balsam fir showed a high variation in density. White pine was less dense and fairly uniformly distributed whereas eastern hemlock had a sparse and patchy distribution. White spruce and exotic species were sparse and tended to be found in areas with lower total regeneration. The comparison with the pre- and post-disturbance park surveys revealed regeneration similar in composition to existing and pre-disturbance forest cover. There are several park management techniques that could benefit park recovery such as the use of donor sites, the importation of favourable conifer species for fill-planting, the culling of some exotic species, and volunteer planting programs.

Keywords: Regeneration, succession, disturbance, Acadian Forest Region, park management, forest ecology, Atlantic Canada

INTRODUCTION

Overview

Urban ecosystems, such as forest parks, are of great importance to city dwellers for aesthetic, recreational, and educational purposes, clean air, and noise buffers. Because of the nature of urban activity, urban forest parks are subject to high levels of disturbance due to fragmentation, biomass removal, and invasive/exotic species (Nowak 1994, Dwyer et al 2003). Furthermore, urban forest parks are subject to the same natural disturbances experienced by native forest ecosystems such as fire and windthrow (Mosseler et al 2003). Natural disturbances in forest parks provide unique research opportunities such as assessing the extent and nature of damage a catastrophic wind disturbance can have, and the pattern of regeneration that will occur considering both the history of intensive park management and the isolation from seed sources that are typical in native forests (Jotcham et al 1992, Neily et al 2004, Burley et al 2007).

---

* Corresponding author: jsteenbe@dal.ca.

Point Pleasant Park is situated in Halifax, Nova Scotia, at the south end of the city's peninsula. In September, 2003, the park was struck by Hurricane Juan and sustained extensive damage. There was public outcry from the citizens of Halifax to recover the forests of the park (PPPIDC 2005). The purpose of this study was to assess the regeneration of coniferous trees in the most disturbed forested areas of Point Pleasant Park to determine whether the park is recovering into a desirable state. The survey was completed in the fall/winter of 2006-2007 and measured regenerating tree-species composition, distribution, and density within the sample area, and as well made a description of the soil drainage and competition within each plot. A comparison between the species composition of the observed regeneration in this study and the forest composition before Hurricane Juan (Jotcham et al 1992, Neily et al 2004) provided data that were used to estimate whether the park was returning to a species composition similar to pre-hurricane conditions. The study results will be useful as baseline data to help discern which park management strategies can best achieve the goal of stable and expedited forest recovery.

OBJECTIVES

- To assess the adequacy of natural regeneration in heavily disturbed areas of the park.
- To compare the observed regeneration with the pre-disturbance forest conditions.
- To identify areas of high and low regenerative density for the possible use of donor sites as a park-recovery management tool.
- To identify which areas might require fill-planting or thinning.
- To assess the extent of park regeneration to exotic tree species.
- To provide baseline data on coniferous regeneration for park management and related decision-making.

Point Pleasant Park

Point Pleasant Park is comprised of 75 ha of forested land, recreational areas, and historical sites, and is situated at the southern tip of the Halifax peninsula. Point Pleasant was the original site chosen for the settlement that was to be Halifax in 1749, but the settlement was moved to present day downtown Halifax shortly after (Kitz &

Castle 1999, Kalkreuth & Duinker 2006). The site was then chosen for military defense of the harbour and city against the French and Americans and vegetation was continuously removed as the park was fortified. In 1866, Point Pleasant officially became a public park on a 999-year lease from the Crown to the City of Halifax. Large-scale vegetation removal ceased and the park vegetation grew into a plant community similar to those found in the Acadian Forest Region (AFR), the forest region in which the park is located (Farrar 1995, Kitz & Castle 1999, Burley et al 2007).

The Acadian Forest Region (AFR) covers the majority of the Maritime Provinces between 43°N and 48°N. It is bordered by the Boreal and Great Lakes-St Lawrence Forest Regions and shows characteristics of both (Rowe 1972, Loo & Ives 2003). The primary species associated with the AFR are red spruce, white pine, eastern hemlock, balsam fir, yellow birch, sugar maple, and red pine. Red spruce is the characteristic climax species associated with the region (Rowe 1972). Old-growth AFR stands are characterized by shade-tolerant, late-successional species such as red spruce and eastern hemlock, but are becoming rare due to agricultural and silvicultural land clearing (Loo & Ives 2003, Mosseler et al 2003, Stewart et al 2003). Most of the AFR is affected by human use and, in Nova Scotia, is dominated now by early-successional, even-aged stands with a relatively high frequency of white spruce, balsam fir, red maple, and white birch (Loo & Ives 2003, Mosseler et al 2003).

The Point Pleasant Park forest, and its place in the AFR, have been described by several authors (Rowe 1972, Simmons et al 1984, Jotcham et al 1992, Neily et al 2004). The park lies within the Atlantic Coastal Region (ACR) described by Simmons et al (1984), but previous surveys of the park found the forest composition to be most similar to the spruce-fir-pine-maple-birch association, which is an early successional complex of the ACR generally found in logged or burned areas (Jotcham et al 1992, PPC 1994, Neily et al 2004).

Point Pleasant Park shows characteristics of two forest sections within the AFR as characterized by Rowe (1972): the East Atlantic Shore section (A.5b) and the Atlantic Uplands section (A.11), (Rowe 1972, Neily et al 2004). Section A.5b is a strip that extends from Cape Breton to Mahone Bay and shows no dominance by red spruce (see Appendix A for species index). Low, dense stands of balsam fir, increased abundance of white spruce, as well as white pine along the shoreline, are all characteristic of section A.5b (Rowe 1972). Section A.11 covers over half of Nova Scotia and the primary species are red spruce, eastern hemlock, white pine, and red maple, with balsam fir present as young growth. The uplands are susceptible to wind and fire disturbances, and have been heavily affected by human development (Rowe 1972). A pre-hurricane ecological survey of Point Pleasant Park stated that a catastrophic disturbance such as a hurricane could cause severe tree mortality due to park's thin soil, steep topography, and presence of even-aged mature conifer stands (Jotcham et al 1991).

Approximately 63 ha (84%) of Point Pleasant Park were forested, and of that 63 ha, approximately 49.2 ha were coniferous stands (76-100% coniferous trees) and 3.8 ha were mixedwood stands (26-75% coniferous trees) (LeHave Forestry Consultants Ltd 1984). The dominant native coniferous species in the park were red spruce and white pine, with occurrences of balsam fir, eastern hemlock, white spruce, and red pine. Native non-coniferous species present included red maple, sugar maple, yellow birch, white birch, red oak, and white ash (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992, Neily et al 2004). Exotic tree species found in Point Pleasant Park include, among others, scots pine, austrian pine, douglas fir, norway spruce, and european beech (Jotcham et al 1992).

The majority of stands in Point Pleasant Park in the 1980s were over 75 years old and considered overmature in commercial forestry terms, or mature in parkland terms. Approximately 47% of the forest stands were even-aged and 43% were uneven-aged (LeHave Forestry Consultants Ltd 1984). The fact the Point Pleasant forests were largely coniferous and mostly mature made them highly susceptible to windthrow. Point Pleasant Park had a dense canopy of red spruce and white pine with slow growth rates throughout the park due to high within-stand competition (Le Have Forestry Consultants Ltd 1984, Jotcham et al 1992). The regeneration beneath the canopy layer was sparse and considered scattered (1-500 stems/ha) to understocked (500-1200 stems/ha), with rare, small patches of adequately stocked (1200-4200 stems/ha) and overstocked (>4200 stems/ha) regeneration (LeHave Forestry Consultants Ltd 1984).

Park Soil

The soils of Point Pleasant Park are classified as brown shaley loam over slate and granite bedrock, and are mostly shallow (Jotcham et al 1992). Shallow loam soils are susceptible to erosion, as are areas with a slope gradient higher than 10%. Approximately 42% of Point Pleasant Park has a slope gradient of 10% or higher, so erosion is a concern (Keys 2004, Neily et al 2004). Due to high precipitation, drainage, and parent material, soils of the park the soils are very acidic (Jotcham et al 1992). Nutrient depletion of soils is also a concern due to the frequent historical removal of coarse woody debris (Kalkreuth & Duinker 2006). The level of soil disturbance due to the hurricane, as well as pre-hurricane soil conditions, can affect the post-hurricane regeneration. High levels of soil disturbance from uprooted trees can hinder advanced regeneration of existing vegetation and favour pioneer and exotic species (Roberts 2004, Burley et al 2007).

There was little evidence of soil compaction due to post-hurricane clean-up operations (Keys 2004). A comparison between disturbed and undisturbed soil samples revealed little soil disturbance from Hurricane Juan (Burley et al 2007). Thus there should be little to no impairment of park regeneration due to soil disturbance from Hurricane Juan or clean-up operations. There is also opportunity for soil improvement if some of the coarse woody debris from hurricane blowdown is left to decompose and improve soil conditions (Kalkreuth & Duinker 2006).

Disturbance History

Natural disturbances, coupled with the vegetation responses to the disturbances, characterize many plant communities (White 1979, Pickett & White 1985). A natural disturbance can be defined as a discrete event or phenomenon that disrupts ecosystem function and structure by changing the physical environment of said ecosystem. Parameters of disturbances, such as frequency, magnitude, and predictability, are extremely variable both in nature and in their effects on ecosystem structure (Picket & White 1985). Wind disturbance is prevalent in many terrestrial ecosystems, especially coastal boreal and temperate forests, such as the AFR (White 1979, Loo & Ives 2003, Mosseler et al 2003). Many factors can affect the resilience of a forest ecosystem to wind disturbance such as topography, substrate/soil quality, and the dominance of intolerant species (White 1979).

Hurricane Juan was a category-2 hurricane that made landfall in Nova Scotia on 29-September-2003 (EC 2004). The stands of Point Pleasant Park sustained significant damage due to the high winds. Up to 75,000 trees (approximately 80% of the trees) within the park were felled (EC 2004, Point Pleasant Park 2005). Point Pleasant Park previously was also subject to other disturbances such as fragmentation by trails, which can lead to the establishment of early-successional, shade-intolerant communities (Burley et al 2007), removal of coarse woody debris, and brown spruce longhorn beetle (*Tetropium fuscum*) outbreaks (Neily et al 2004, Kalkreuth & Duinker 2006). The disturbance history of the area has generated concern about the regenerative capabilities of the park.

The process of succession is dependent on factors such as the nature of the disturbance, characteristics of the disturbed site, species composition, and structure of the pre-disturbance community (Watt 1947, White 1991). Early succession is most often characterized by unstable population dynamics composed of shade-intolerant, short-lived species with high dispersal. As the forest community matures, it tends to become more stable and is comprised of shade-tolerant, long-lived species with lower dispersal (Connell & Slatyer 1977, Galipeau et al 1997, Mosseler et al 2003). These late-successional climax species tend to be replaced by the same species when small disturbances such as individual tree death occur (Pickett & White 1985, Mosseler et al 2003).

Many stands in the AFR are kept in a sub-climax state due to adverse environmental conditions (substrate and grade); these stands are comprised of mainly balsam fir, white spruce, black spruce, red maple, and tamarack. In the Galipeau et al (1997) study of an eastern boreal forest similar to the AFR, balsam fir and white spruce were important indicators of post-disturbance successional progress. White spruce was a better disperser and was present earlier and farther from preserved stands. Balsam fir invaded the disturbed areas by advancing fronts with lower dispersal, and was limited by the absence of shade. The species composition and abundance of seedlings in the disturbed areas of Point Pleasant Park will give an insight into the successional and regenerative progress/status of the park. Also, the data will indicate whether the species composition of the park is within the ecological boundaries of native and healthy AFR.

METHODS

Sample Design

The survey method used to assess coniferous regeneration in Point Pleasant Park was a stratified systematic plot-count sample method, and was completed in the fall/winter of 2006-2007. Broadleaf tree species were excluded from the sampling due to time constraints. The park was stratified into polygons defined by existing trails (Fig 1) and each stratum was given one of three levels of data collection priority based on visual inspection: 1) first-priority sampling, 2) second-priority sampling, and 3) no measurement. Strata showing the highest levels of disturbance were assigned the highest priority.

Transects were laid out at 10 m intervals and were oriented in the most efficient way based on the shape of each stratum. Plots were laid at 10 m intervals along each transect, giving a plot count of 100 plots/ha. Each plot was 20 m^2, giving a sample area of 2,000 m^2/ha with a total of 1,246 plots.

Plot Measurements

Each plot was assessed for individual tree species, individual tree heights, drainage, and competition:

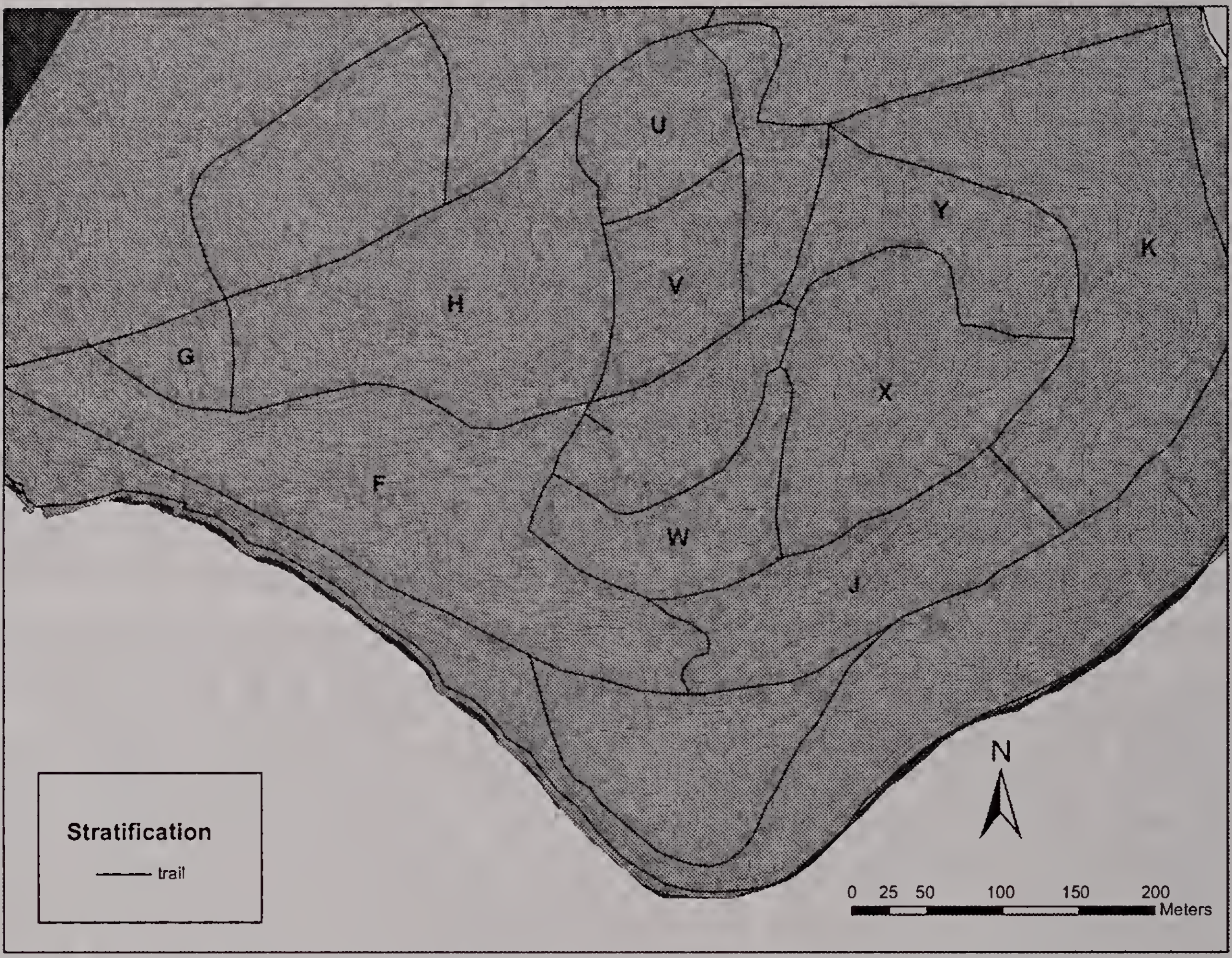


Fig 1 Stratification of the sample area within Point Pleasant Park.

1. Species. All coniferous trees taller than 10 cm and shorter than 200 cm within each plot were counted and identified using Farrar's (1995) guide to Canadian trees.
2. Height. All counted trees were categorized into three height categories: 10 cm – 30 cm, 31 cm – 100 cm, and 101 cm – 200 cm.
3. Drainage. Three categories of soil drainage were used to describe each plot: wet, fresh, and dry.
4. Competition. The main source of competition was assessed in each plot and assigned to one of four categories: low competition, grass, herbaceous growth, and woody shrubs.

Research Equipment

A compass was used to orient each transect using landmarks; landmarks were reassessed every few plots to ensure reliability. A hip chain would have been more accurate for laying transects but was not used due to time constraints and the unfavourable waste string left behind. Metal stakes and a 2.5 m plot-cord were used to layout each plot.

Data Analysis

Transect orientation and plot location, in each stratum, were mapped using ArcGIS Desktop V.9.1. ArcMap was used to map the density and distribution of each species and all species combined in the sample area. Density (stems/ha) and proportion of total regeneration (%) for each species and all species combined were tabulated for each stratum and the entire sample area.

The coniferous regeneration observed in this study was compared to two previous surveys conducted in Point Pleasant Park, using ArcGIS Desktop V.9.1. In the survey conducted by Jotcham et al (1992), aerial photographs were used to divide the forested area of Point Pleasant Park into 10 ecological areas. Using a 50 m x 50 m grid, 15 m x 15 m plots were established every 100 m and an inventory of all tree species taller than 1 m was taken. For the comparison in this study, the total stem counts of all coniferous species in these plots were converted to stems/ha and compared to stems/ha observed in this study in the same areas. The areas described by Jotcham et al (1992) were mapped using ArcMap and overlaid on the density distribution maps created for this study.

The Neily et al (2004) post-disturbance survey used 1:10,000 aerial photographs to classify Point Pleasant Park vegetation types using the Forest Ecosystem Classification (FEC) system as defined by Keys et al (2003). Using ArcMap, the described vegetation types were mapped and overlaid on the density distribution maps created for this study to conduct a descriptive comparison.

RESULTS

Point Pleasant Park Regeneration

A density distribution map was created for each of the seven species categories used in analysis: all species combined, red spruce, white pine, balsam fir, eastern hemlock, white spruce, and exotic species (Table 1). There was a large observed variation of seedling density in the sample area, with the highest densities found in the northern and western section of the sample area and the lowest in the south-eastern area. The highest density was in stratum G at 5407 stems/ha, and the lowest density was in stratum J at 917 stems/ha (Table 2, Fig 2). The dense regeneration patch found in the north-eastern section of stratum X (4639 stems/ha) and the south-western section of stratum Y (4200 stems/ha) was adjacent to a surviving immature red spruce stand that lies in the centre of stratum X, where there was no data collection. Other gaps in data collection in the study area included the Martello Tower fortification on the northern edge of stratum H, the heather patch in the centre of stratum W, and the Cambridge Battery fortification (Fig 1).

The map of the red spruce density distribution (Fig 3) illustrates how regeneration in the sample area was comprised mainly of red

Table 1 Species index

Abbreviation	Common Name	Scientific Name
AP	Austrian pine	*Pinus nigra*
BF	Balsam fir	*Abies balsamea*
BS	Black spruce	*Picea mariana*
DF	Douglas fir	*Pseudotsuga menziesii*
EH	Eastern hemlock	*Tsuga canadensis*
WC	Eastern white cedar	*Thuja occidentalis*
EB	European beech	*Fagus sylvatica*
NS	Norway spruce	*Picea abies*
RM	Red maple	*Acer rubrum*
RO	Red oak	*Quercus rubra*
RP	Red pine	*Pinus resinosa*
RS	Red spruce	*Picea rubens*
SP	Scots pine	*Pinus sylvestris*
SM	Sugar maple	*Acer saccharum*
TA	Tamarack	*Larix laricina*
WA	White ash	*Fraxinus americana*
WB	White birch	*Betula papyrifera*
WP	White pine	*Pinus strobus*
WS	White spruce	*Picea glauca*
YB	Yellow birch	*Betula alleghaniensis*

spruce, with the exception of strata G and H where balsam fir was the dominant regenerating species, at 74 and 49% of the total regeneration, respectively. Red spruce was the only species with a regeneration frequency greater than 50% for the entire sample area (Fig 9). White spruce tended to be found in areas with lower total regeneration (Fig 8). The highest observed density of white spruce was in stratum J, at 96 stems/ha, which also had the lowest total regeneration, at 917 stems/ha. White spruce was not found in stratum G.

Balsam fir showed a high variation in density across the sample area (Fig 4), ranging from 146 stems/ha (3% of total) in stratum Y to 3981 stems/ha (74% of total) in stratum G. Aside from strata G and H, and several isolated dense plots, balsam fir was sparsely distributed. Despite lower densities in some parts, balsam fir, like red spruce, is found in every stratum.

White pine was less dense and fairly uniformly distributed throughout the sample area (Fig 5), comprising 2-12% of the observed regeneration in all strata. White pine density was lower along the southeastern side of the sample area, in strata K, J, W and the southern portion of X. White pine was the third and final species to be found in every stratum.

Eastern hemlock was rare, with a density of just 33 stems/ha for the entire sample area. Strata G and V were the only areas where

Table 2 Summary data for each stratum and the entire sample area

Stratum	Species	Stems	Stems/ha	% of Total
G (0.41 ha)	RS	56	1037	19
	WP	15	278	5
	BF	215	3981	73
	EH	6	111	2
	WS	-	-	-
	Exotic	-	-	-
	Total	292	5407	100
H (3.05 ha)	RS	863	2358	45
	WP	69	188	4
	BF	964	2584	49
	EH	6	16	0
	WS	19	52	1
	Exotic	18	49	1
	Total	1921	5249	100
F (3.74 ha)	RS	524	1065	50
	WP	82	167	8
	BF	316	642	30
	EH	29	59	3
	WS	24	49	2
	Exotic	66	134	6
	Total	1041	2116	100
V (1.00 ha)	RS	423	2747	74
	WP	62	403	11
	BF	41	266	7
	EH	33	214	6
	WS	3	19	0
	Exotic	9	58	2
	Total	571	3708	100
U (0.93 ha)	RS	144	1162	53
	WP	31	250	11
	BF	84	677	31
	EH	3	24	1
	WS	1	8	0
	Exotic	9	73	3
	Total	272	2194	100
K (3.84 ha)	RS	402	705	58
	WP	63	111	9
	BF	138	242	20
	EH	3	5	0
	WS	49	86	7
	Exotic	37	65	5
	Total	692	1214	100

Table 2 *Cont'd*

Stratum	Species	Stems	Stems/ha	% of Total
W (1.12 ha)	RS	76	679	64
	WP	2	18	2
	BF	34	304	29
	EH	1	9	1
	WS	6	54	5
	Exotic	-	-	-
	Total	119	1063	100
X (2.30 ha)	RS	790	3798	82
	WP	22	106	2
	BF	131	630	14
	EH	1	5	0
	WS	18	87	2
Exotic	5	24		1
	Total	967	4649	100
Y (1.37 ha)	RS	771	3743	89
	WP	54	262	6
	BF	30	146	3
	EH	-	-	-
	WS	7	34	1
	Exotic	3	15	0
	Total	865	4199	100
J (1.75 ha)	RS	127	583	64
	WP	9	41	5
	BF	38	174	19
	EH	1	5	1
	WS	21	96	11
	Exotic	4	18	2
	Total	200	917	100
Total (19.51 ha)	RS	4176	1676	60
	WP	409	164	6
	BF	1973	792	28
	EH	83	33	1
	WS	148	59	2
	Exotic	151	61	2
	Total	6940	2785	100

hemlock density exceeded 100 stems/ha, with 111 and 214 stems/ha, respectively. Hemlock had a patchy distribution and tended to be found in areas with denser total regeneration in the northwestern part of the sample area (Fig 6). No hemlock was found in stratum Y.

Like white spruce, the exotic species found in Point Pleasant Park, with scots pine as the majority, and some austrian pine, douglas fir, and norway spruce, showed density distribution patterns different from the rest of the sampled species (Fig 7). They were found not to exceed a 20% regeneration frequency in the sample area and

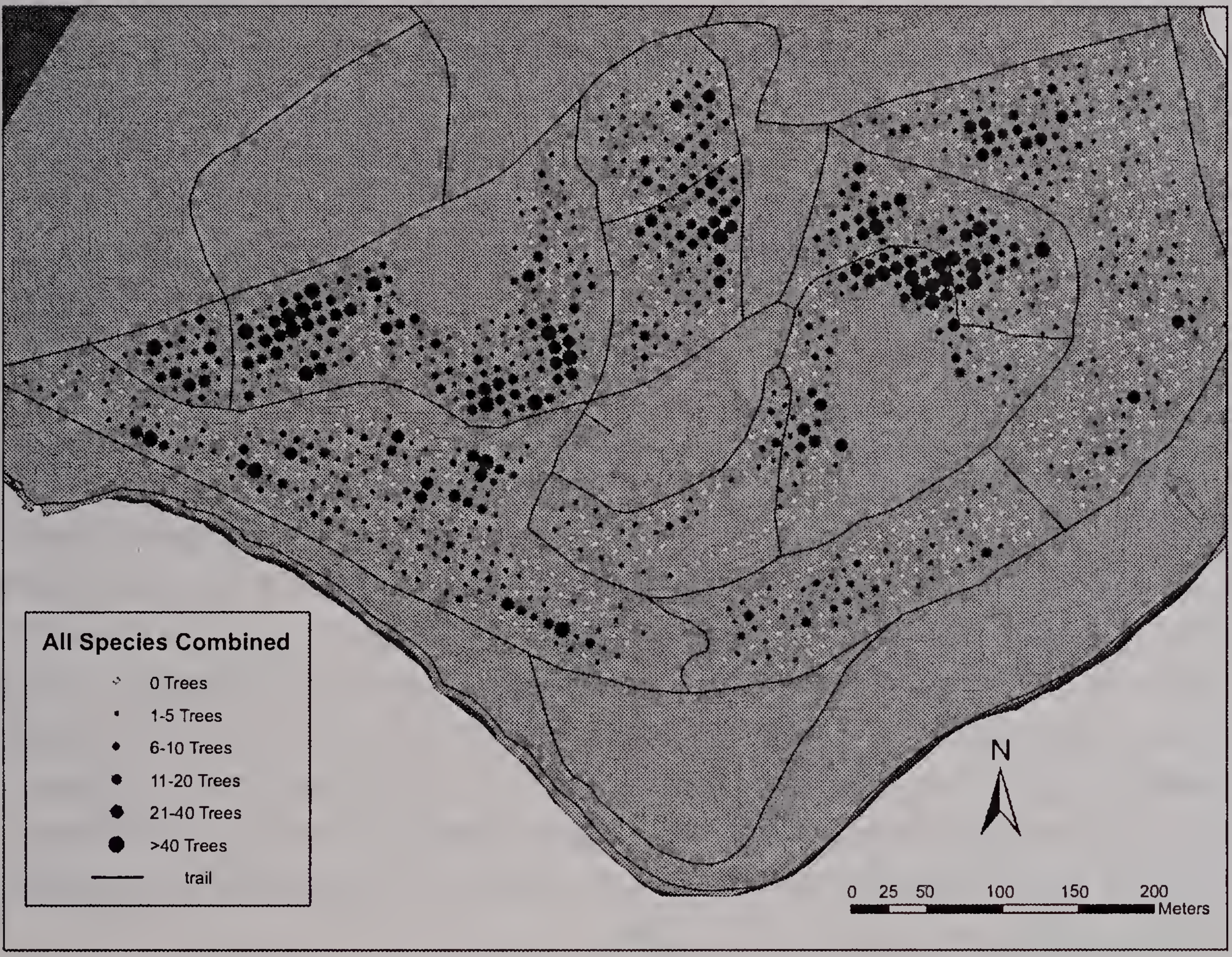


Fig 2 The density distribution of all species in the sample area of Point Pleasant Park.

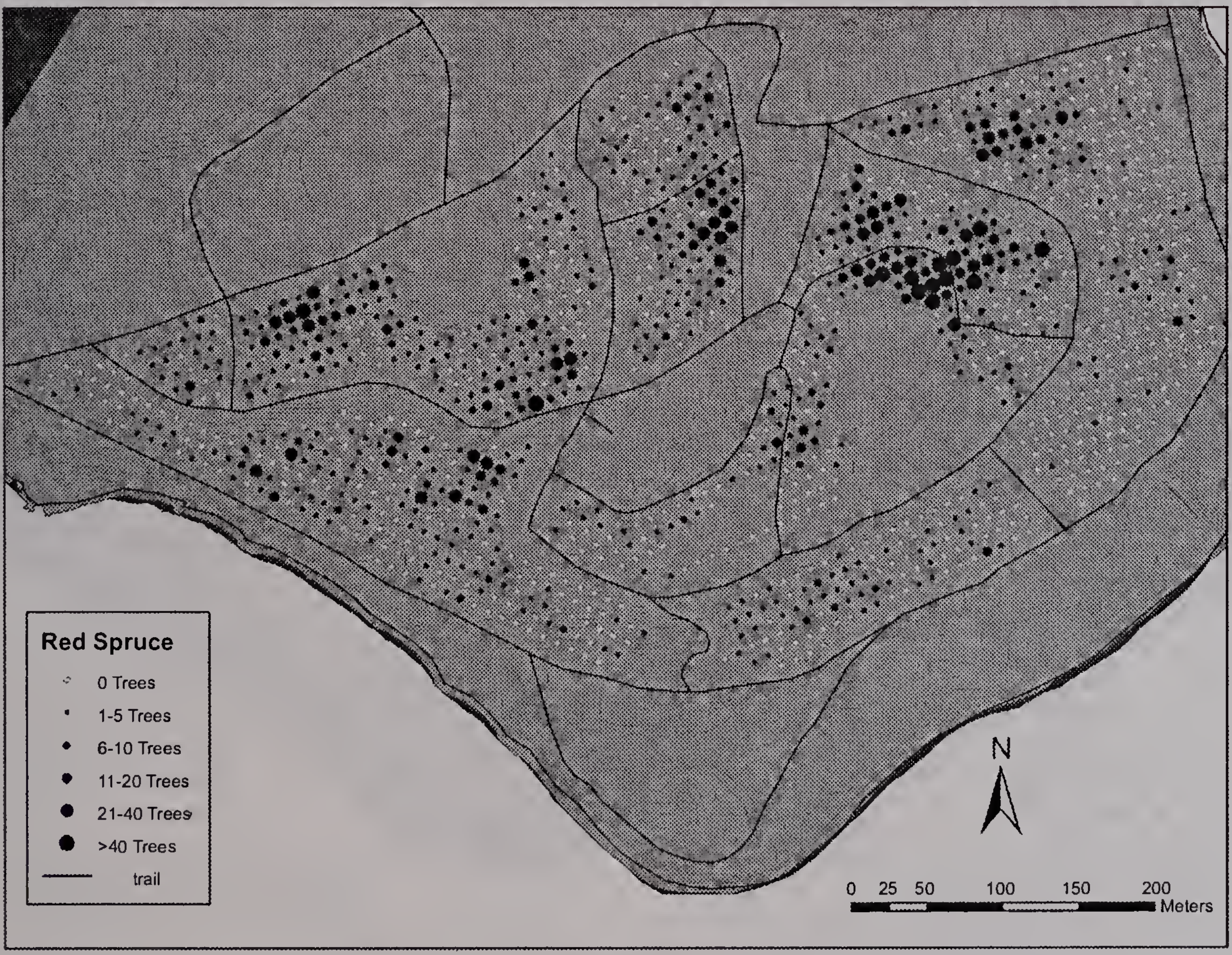


Fig 3 The density distribution of red spruce in the sample area of Point Pleasant Park.

tended to be found in more disturbed areas such as strata K and J. Exotic species were found only in low density; never more than 5 individuals per plot and only once exceeding 100 stems/ha, in stratum F. There was also a large patch of exotic species found in the disturbed centre of stratum F. In addition, stratum F had the highest density and proportion of total regeneration of exotics, with134 stems/ha and 6%, respectively. No exotic species were found in strata G and W.

Height Distribution

The distribution of regenerating trees among the three height categories varied among the species sampled (Fig 10). Approximately 50% of all white pine, balsam fir, and exotic species counted were 10-30 cm in height. Approximately 10% of all species were 101-200 cm tall except for white spruce and eastern hemlock, where approximately 30% of the trees were 101-200 cm tall. Red spruce, white spruce, and eastern hemlock differed from white pine, balsam fir, and the exotic species in that the majority of trees counted were in the 31-100 cm category. Approximately 50% of the total observed regeneration was 31-100 cm tall.

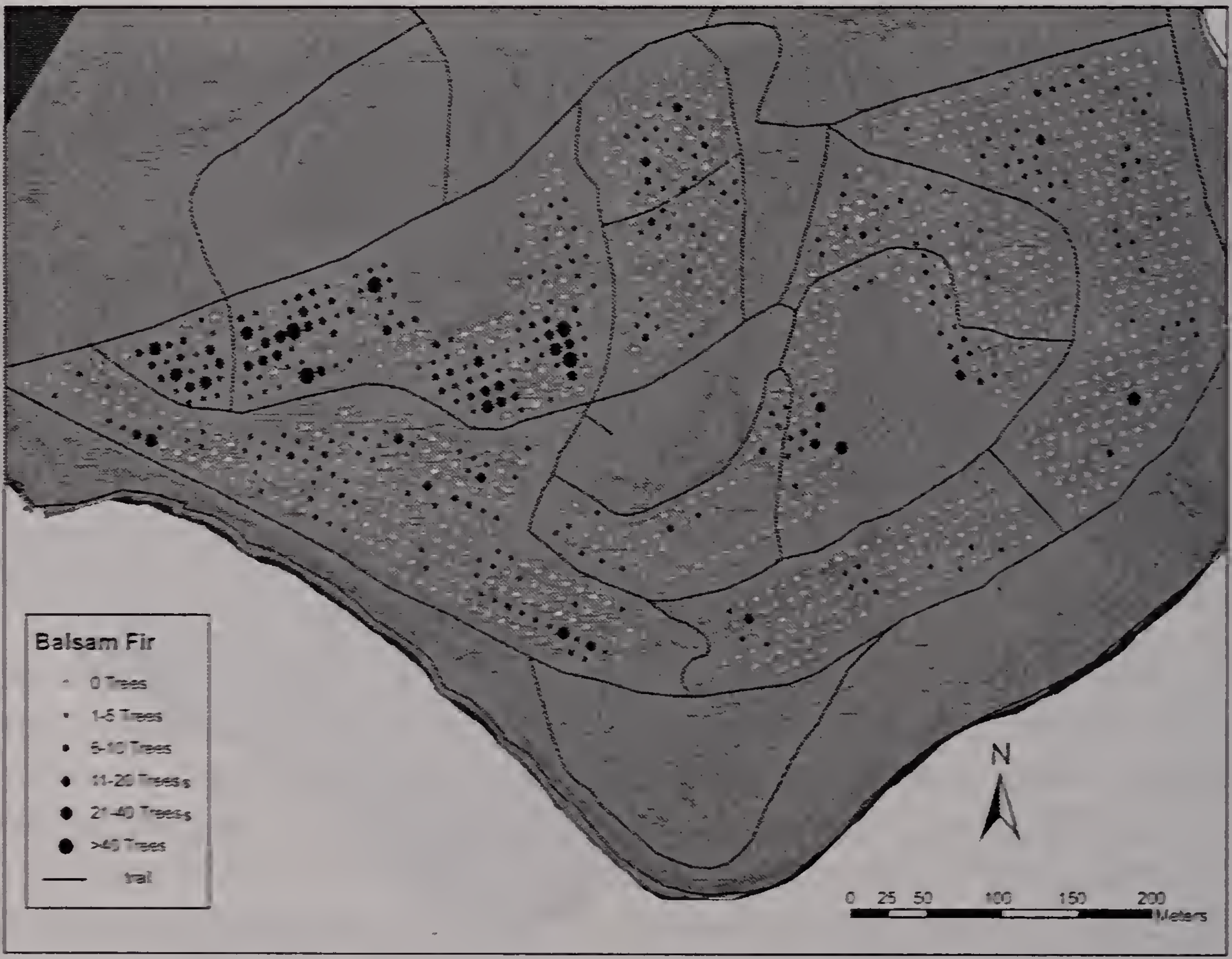


Fig 4 The density distribution of balsam fir in the sample area of Point Pleasant Park.

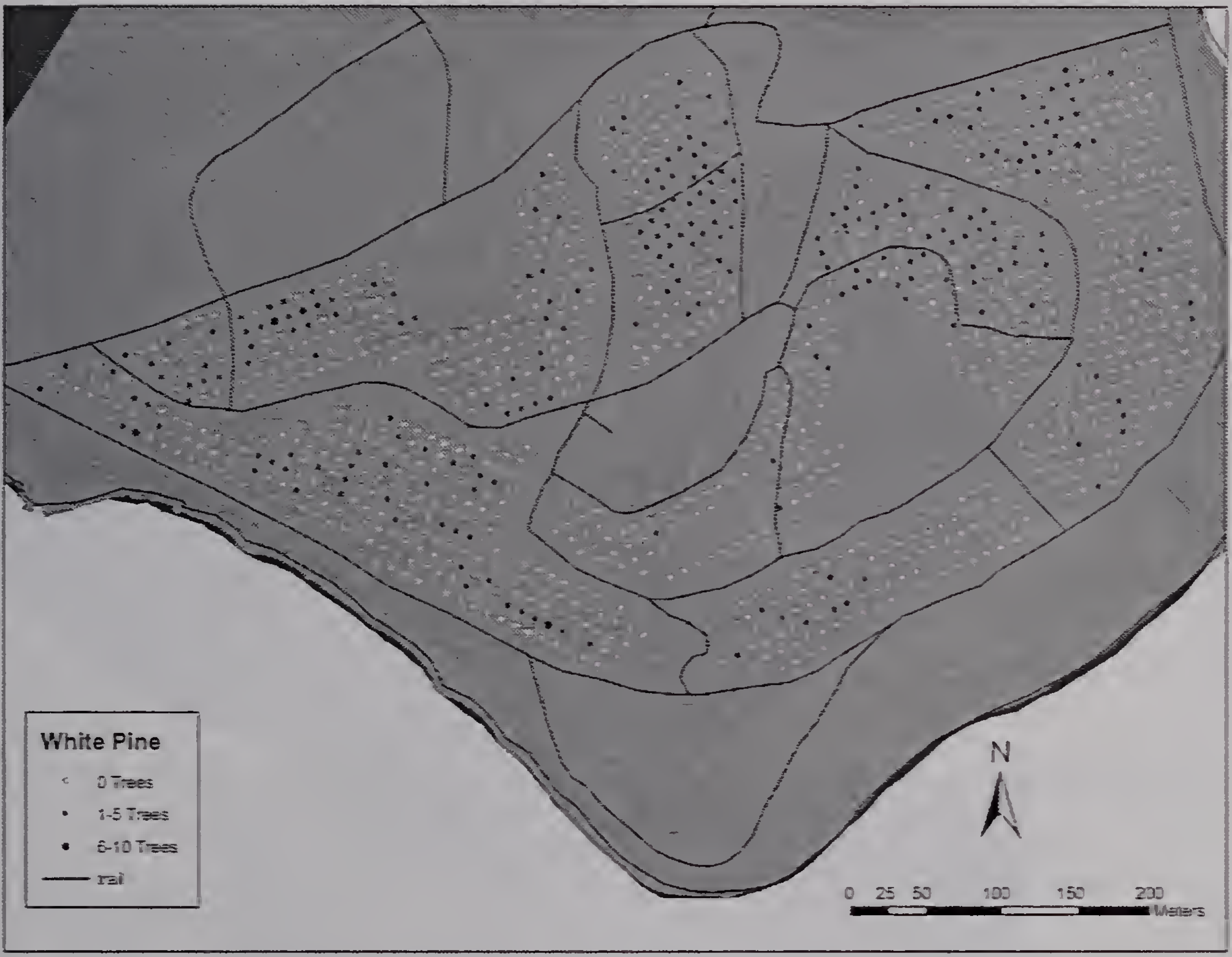


Fig 5 The density distribution of white pine in the sample area of Point Pleasant Park.

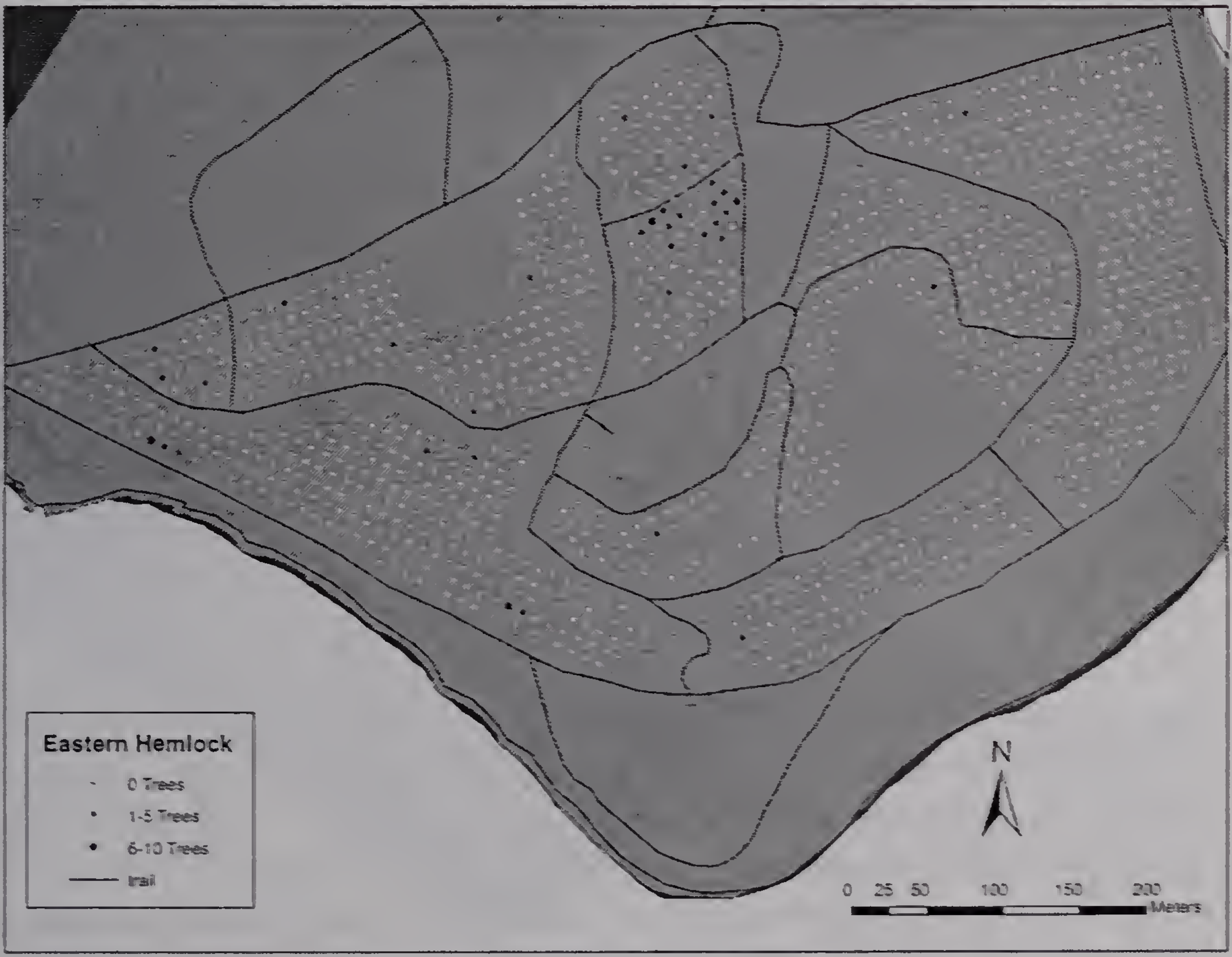


Fig 6 The density distribution of eastern hemlock in the sample area of Point Pleasant Park.

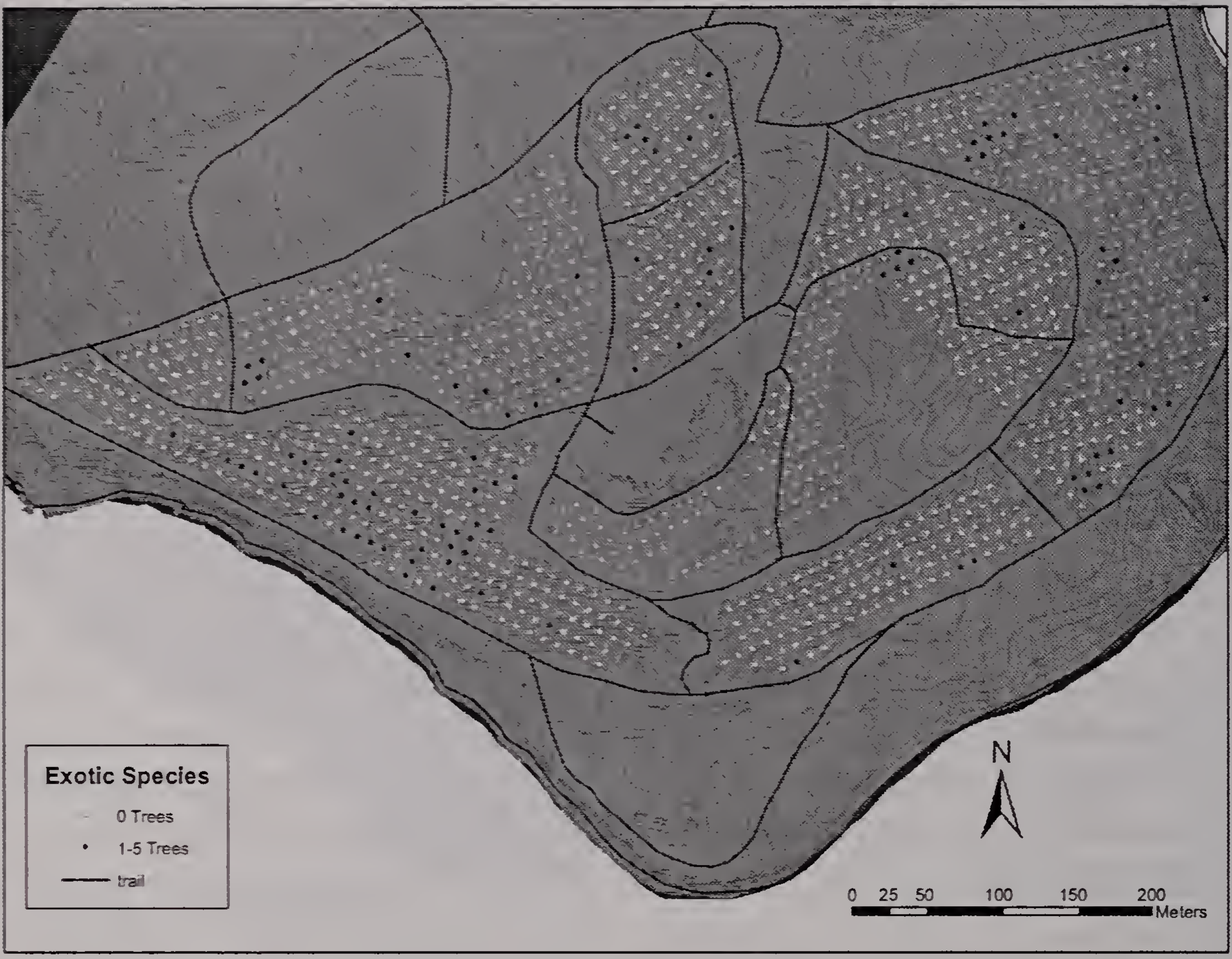


Fig 7 The density distribution of exotic species in the sample area of Point Pleasant Park.

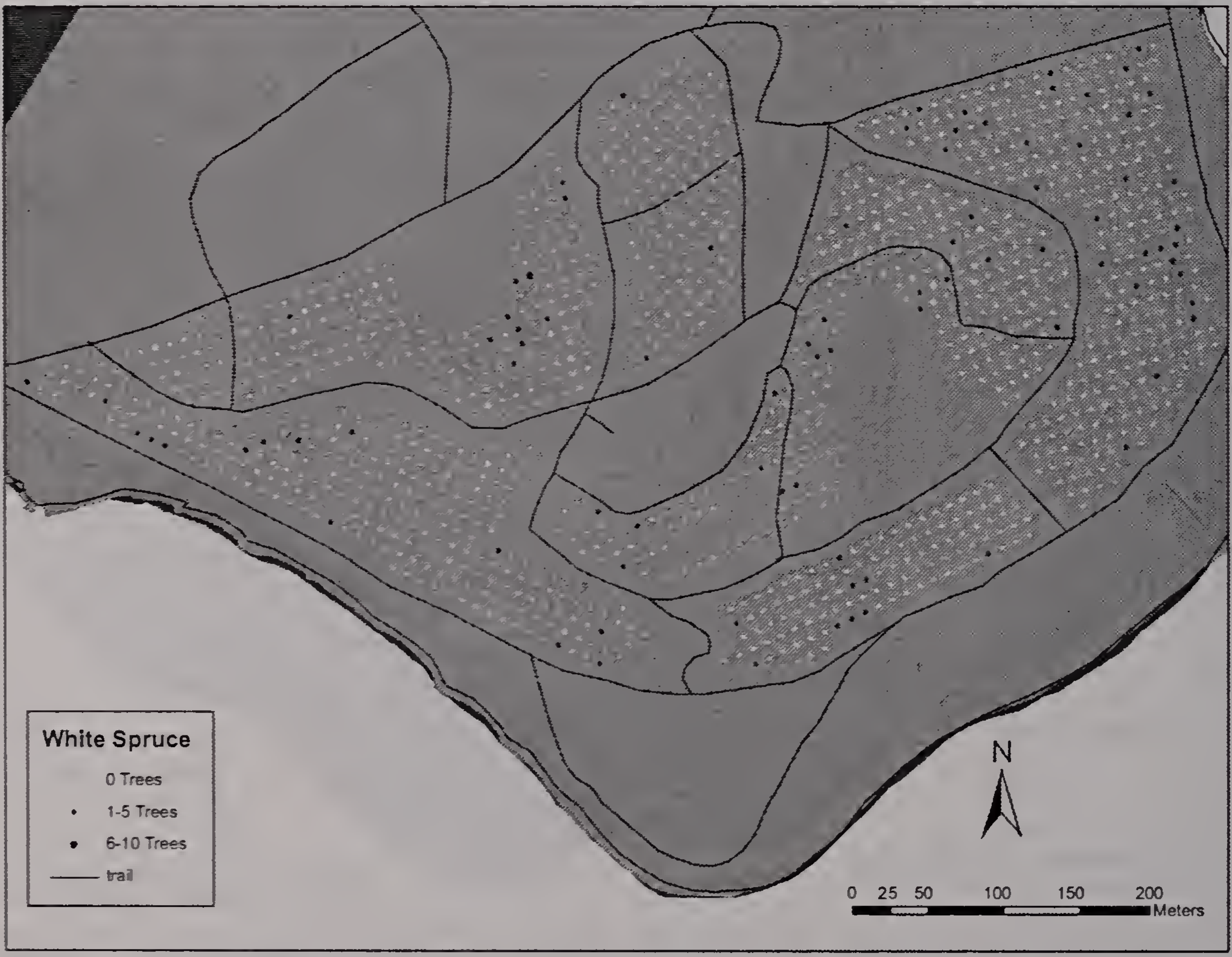


Fig 8 The density distribution of white spruce in the sample area ofPoint Pleasant Park.

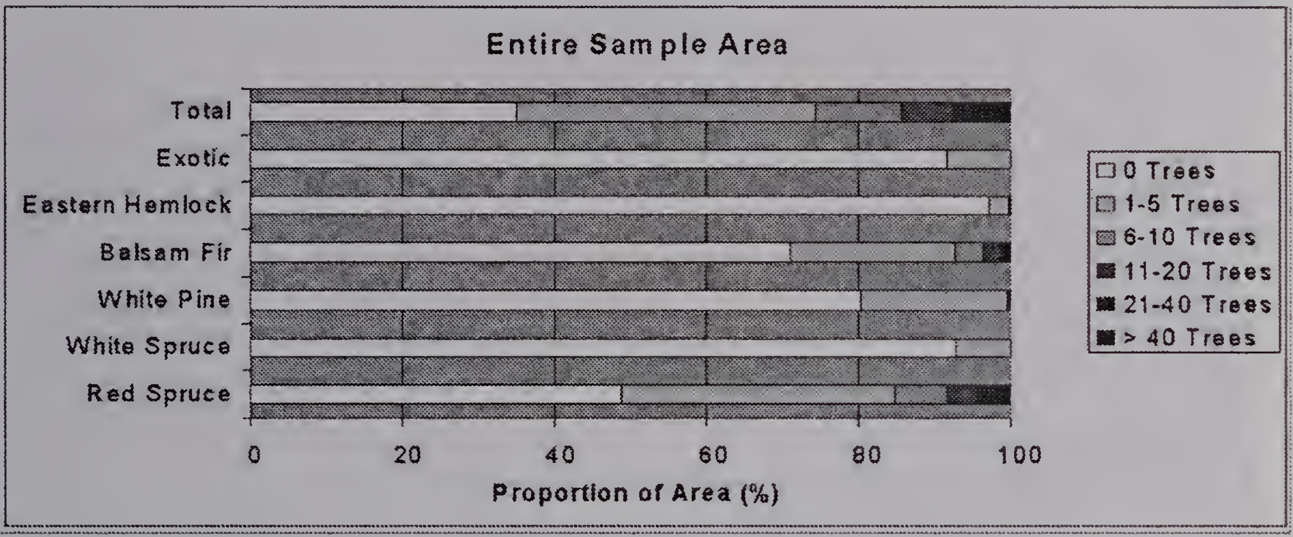


Fig 9 Regeneration frequency histogram illustrating the proportion of area covered by each density category in the entire sample area.

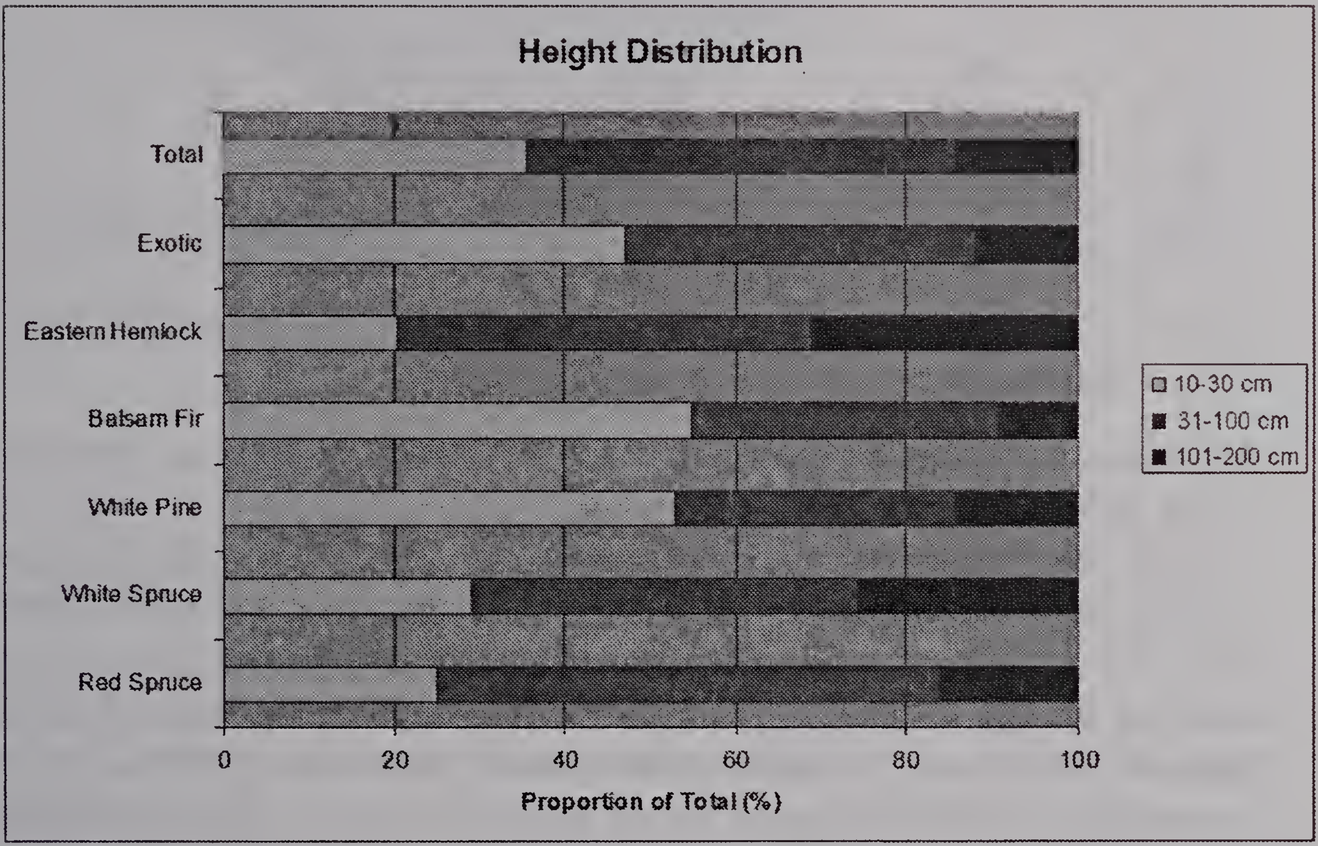


Fig 10 Height distribution of regenerating species in the sample area of Point Pleasant Park.

Pre-Disturbance Survey Comparison

The stand division of Jotcham et al (1992) was used for a comparison with the regeneration observed in this study (Fig 11). Their area 2 covers the majority of the sample area, consisting of all of stratum G, H, U, V, K, X, Y, and the majority of stratum F. Red spruce was the dominant species in area 2 in the pre-disturbance survey and this survey (Table 3). There was a large increase in balsam fir density in areas 2, 5 and 8 from pre-disturbance conditions, especially area 2 where balsam fir increased from 115 stems/ha to 860 stems/ha. However, there was certainly a skew in the data towards larger increases from pre-disturbance conditions, especially

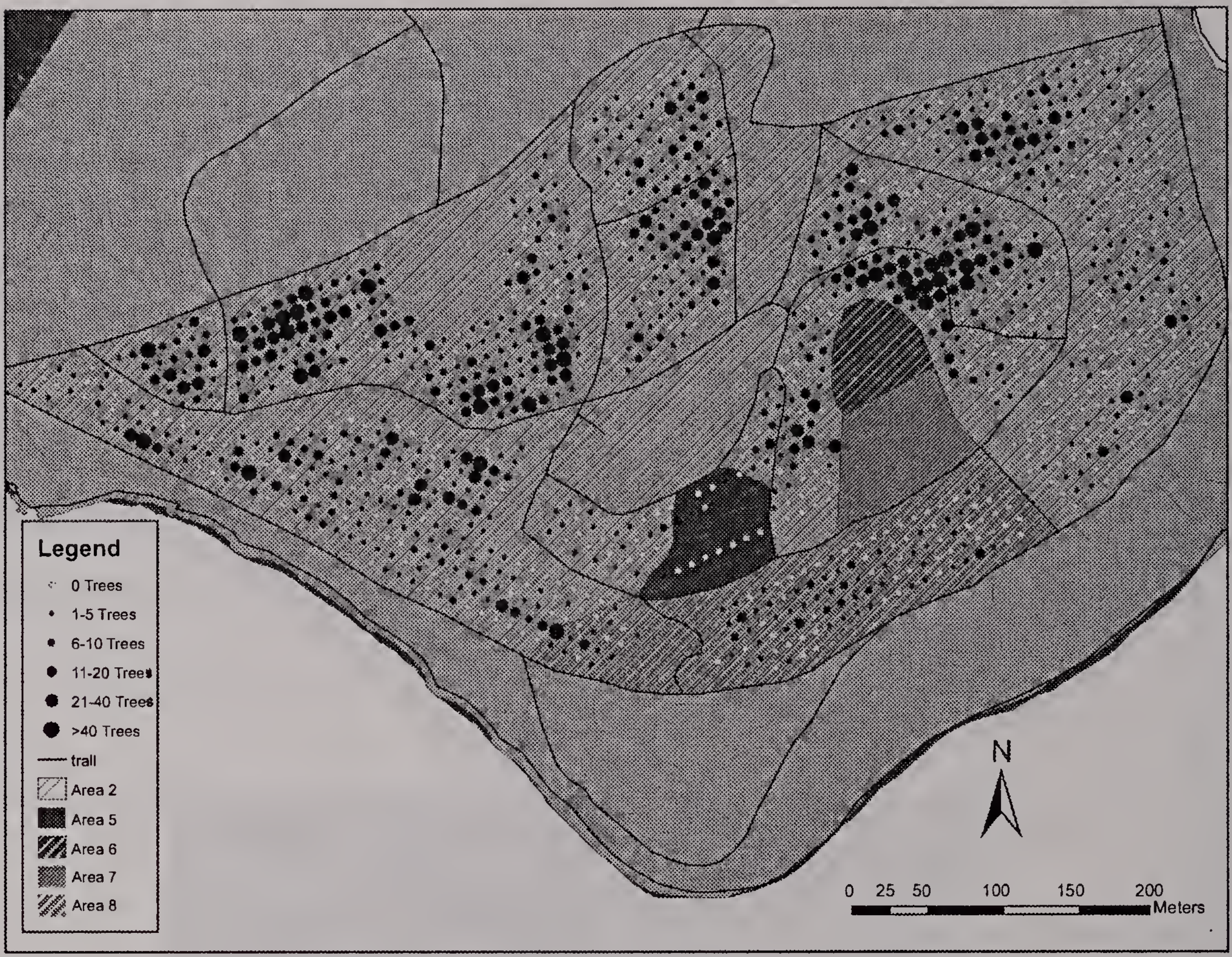


Fig 11 Overlay of observed regeneration and the Jotcham et al. (1992) park survey classification.

in balsam fir, because stems under 1 m in height were not counted in the Jotcham et al (1992) survey.

White pine showed small increases in density from pre-disturbance conditions in all three areas. A large increase in eastern hemlock from pre-disturbance conditions was also seen, especially in areas 5 and 8 where it was not observed before the hurricane, though it remained at very low densities (the highest being 38 stems/ha in area 2). Exotic species in area 8 decreased from 80 stems/ha before Hurricane Juan to 29 stems/ha after Hurricane Juan and remained absent in area 5 in the post-disturbance survey. In area 2, exotic regeneration was nearly twice as dense as during pre-disturbance conditions. White spruce decreased in density from pre-disturbance conditions in areas 2 and 8, more so in area 8 where it was surpassed by red spruce as the dominant species. There was an increase in white spruce from pre-disturbance conditions in area 5 (34 stems/ha) but it was not present before the hurricane.

Areas 6 and 7 were also found within the sample area of this study, but no data were collected in them as they were occupied by dense white birch and red spruce thickets, respectively.

Post-Disturbance Survey Comparison

Neily et al (2004) identified nine vegetation types, five of which overlapped the sample area of this study: VT9, VT10 (unit 1), VT10

Table 3 Comparison of the observed regeneration and the regeneration in the overlapping areas defined by the Jotcham et al. (1992) Point Pleasant Park survey

Area	Species	Stems/ha (1992)	% of Total	Stems/ha (2006)	% of Total
2 (17.36 ha)	RS	894	74	1850	61
	WP	107	9	175	6
	BF	115	10	860	28
	EH	4	0	38	1
	WS	58	5	56	2
	Exotic	36	3	67	2
	Total	1215	100	3046	100
5 (0.56 ha)	RP	267	100	-	-
	RS	-	-	431	66
	WP	-	-	17	3
	BF	-	-	155	24
	EH	-	-	17	3
	WS	-	-	34	5
	Exotic	-	-	-	-
	Total	267	100	367	100
8 (1.59 ha)	RS	204	18	593	48
	WP	44	4	111	9
	BF	107	9	400	33
	EH	-	-	4	0
	WS	702	62	89	7
	Exotic	80	7	29	2
	Total	1138	100	1229	100

(unit 2), VT11 (unit 1), and VT11 (unit2) (Table 4, Fig 12). VT9 *Red spruce-Hemlock, Starflower* covered all of stratum G, and the eastern ends of strata F and H. The dominant regenerating species was balsam fir (2367 stems/ha, 67% of total). Red spruce represented the second most-abundant species, and eastern hemlock was more dense than in other vegetation types (139 stems/ha). The only other area with higher densities of eastern hemlock than VT9 was stratum V, located in VT10 (unit 1).

VT10 (unit 1) *Red spruce-White pine, Bracken* covered most of the study area, and was similar to area 2 in the Jotcham et al (1992) survey. VT10 (unit 1) followed the most common regeneration pattern in the park: red spruce was dominant, with smaller components of balsam fir, white pine, eastern hemlock, white spruce, and exotic species. VT10 (unit 2) *Red spruce-White pine, Bracken, with Old Field Patches* covered all of stratum W and the portion of stratum X on the eastern edge of the surviving immature red spruce stand. This vegetation type had little regeneration, with a dominance of

Table 4 Comparison of the observed regeneration and the regeneration in the overlapping vegetation types defined by the Neily et al. (2004) Point Pleasant Park survey

Vegetation Type	Species	Stems/ha	% of Total
VT9	RS	665	19
WP	228	6	
BF	2367	67	
EH	139	4	
WS	76	2	
Exotic	44	1	
Total	**3519**	**100**	
VT10 (unit 1)	RS	2421	65
WP	220	6	
BF	909	24	
EH	41	1	
WS	53	1	
Exotic	76	2	
Total	**3721**	**100**	
VT10 (unit 2)	RS	802	64
WP	35	3	
BF	317	25	
EH	5	0	
WS	94	8	
Exotic	-	-	
Total	**1252**	**100**	
VT11 (unit 1)	RS	452	54
WP	57	7	
BF	217	26	
EH	-	-	
WS	62	7	
Exotic	45	5	
Total	**833**	**100**	
VT11 (unit 2)	RS	2423	44
WP	77	1	
BF	3038	55	
EH	-	-	
WS	-	-	
Exotic	-	-	
Total	**5538**	**100**	

red spruce and balsam fir. Most of the regeneration was adjacent to the residual spruce stand in stratum X.

VT11 (unit 1) *Red spruce-Balsam fir, Schreber's moss* (Mature) overlapped the more disturbed, eastern portion of the sample area and overlapped the majority of stratum K, the northern half of stratum J, and the southern portions of strata X and Y. VT11 (unit 1) had the lowest regeneration density of all the vegetation units,

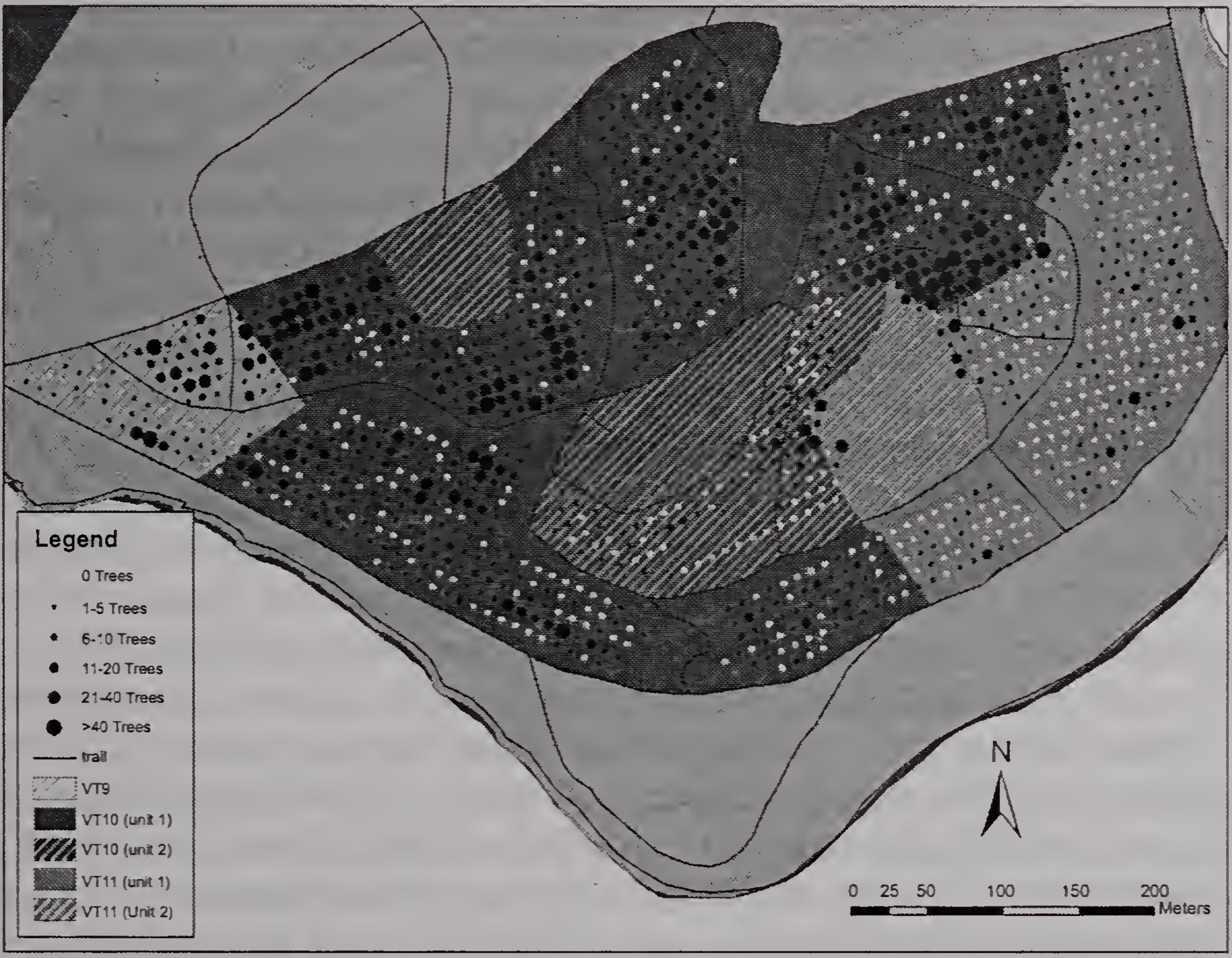


Fig 12 Overlay of observed regeneration and the Neily et al. (1992) park survey classification.

at 833 stems/ha, and was dominated by red spruce and balsam fir. White spruce density in this vegetation type was 62 stems/ha and constituted 7% of the total regeneration. VT11 (unit 2) Red spruce-Balsam fir, Schreber's moss (Immature) consisted mainly of the surviving red spruce stand, and overlapped only a few plots with high densities of red spruce and balsam fir regeneration.

DISCUSSION

Successional Response of Point Pleasant Park

Concern has been expressed about the regenerative capabilities of the park, based on existing vegetation surveys. It is possible that due to the isolation of Point Pleasant Park from other possible seed sources, and high fragmentation of the park due to trails, the post-disturbance regeneration could consist largely of shade-intolerant, short-lived, pioneer tree species (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992, Neily et al 2004). While this pattern of succession after stand-replacing disturbances is typical in native Acadian forest, as well as most other forest types (White 1979, Loo & Yves 2003, Mosseler et al 2003), it is a concern in Point Pleasant Park for two reasons. First, the park may stay in a sub-climax community dominated by short-lived species, such as white spruce and balsam fir, due to poor soil conditions and high disturbance levels (Mosseler et al 2003, Neily et al 2004, Burley et al 2007). Second, Point Pleasant Park is a recreational area, and the aesthetic value of the park forests is of high importance. Prompt regeneration into red spruce-white pine-eastern hemlock forest, typical of native Acadian old growth, could be an important park management goal (Neily et al 2004, Keys 2005). Due to the possibility of exposed mineral soil and fragmentation by trails, there is also a concern that exotic species may regenerate rapidly in the park (Moola & Vasseur 2004, Keys 2005).

Red spruce was the dominant overstorey species in Point Pleasant Park prior to hurricane Juan, and was likewise found to comprise 60% of the regeneration in the sample area. Strata G and H were the only areas where red spruce did not comprise at least 50% of the observed regeneration. It is likely that Hurricane Juan did not remove enough pre-hurricane vegetation, the main source of seed dispersal in disturbed areas, to significantly alter the forest composition of Point Pleasant Park (Castelli et al 1999, Burley et al 2007). The immature spruce stand found in the centre of stratum X is one such source for seed dispersal and is most likely the seed source for the dense red spruce regeneration seen to the north-east of the stand. Red spruce is a long-lived species (250-450 years) and is a shade-tolerant, climax species in native Acadian Forests (Mosseler et al 2003), so it is a favourable species for regeneration.

White pine was the other dominant, pre-disturbance canopy species, but was not found to be regenerating in nearly the same density as red spruce. Despite the low observed pre-disturbance regeneration of white pine (LeHave Forestry Consultants Ltd 1984), it was predicted that white pine would be dominant in regeneration because of both the residual white pine scattered throughout the disturbed area and the affinity of white pine seedlings for exposed mineral soil caused by uprooted trees and scarification from clean-up operations (Neily et al 2004). In comparison to other observed species, white pine was relatively evenly distributed through both heavily disturbed areas and less disturbed areas, but the expected dense white pine regeneration was not observed; strata U and V were the only areas where white pine accounted for more than 10% of the observed regeneration.

There are several possible explanations for the lack of dense white pine regeneration. It has been observed that white pine has cyclic propagule dispersals, with good seed crops occurring every three to five years (Burns & Honkala 1990). Also, although white pine was a dominant canopy species and constituted much of the forest basal area before the hurricane, it was much less dense than red spruce, and therefore had fewer individuals for seed dispersal. For example, in area 2 in the Jotcham et al (1992) survey, red spruce and white pine constituted 46 and 35% of the basal area, respectively, yet white pine only had a total of 104 stems, compared to 760 red spruce stems. A final hypothesis is that there was a lack of exposed mineral soil that is well suited for white pine regeneration, due in part to the high amount of ground covered by coarse woody debris and litter. Burley et al (2007) found no significant difference in soil quality between disturbed and undisturbed plots. Like red spruce, white pine is a longer lived, climax species in native Acadian forest (Loo & Yves 2003, Mosseler et al 2003) and a main constituent of the ACR, where Point Pleasant Park is located (Simmons et al 1984), so its regeneration should be closely monitored by park managers.

Eastern hemlock was found in rather low densities throughout the park; the only areas where hemlock constituted more than 1% of the observed regeneration were strata G, F, and V (stratum V had the highest densities at 214 stems/ha). Eastern hemlock is a climax, shade-tolerant species, typical of AFR old growth that would certainly be a favourable species for regeneration in Point Pleasant Park. Although eastern hemlock had the lowest regeneration of all species in the sample area, it was never a large component of the park before Hurricane Juan (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992) and was in fact observed at higher densities than in pre-disturbance surveys.

Balsam fir and white spruce are two pioneer species that each have properties indicative of the level of disturbance in an area (Galipeau et al 1997, Mosseler et al 2003). White spruce is a good disperser and tends to be the first coniferous colonizer in the most disturbed areas whereas balsam fir is not as good a disperser and tends to be found in more shaded areas, with some intact canopy and existing balsam fir regeneration (Galipeau et al 1997). The largest concentrations of balsam fir were found in strata G and H, where it was the dominant regenerating species. These areas were adjacent to less-disturbed areas in the northern portion of the park and had some intact canopy (mainly in stratum G). The more-disturbed, eastern strata, such as J, K, and W with lower total regeneration, had higher relative white spruce densities. The higher white spruce regeneration in these areas may be indicative of higher disturbance levels and slower successional progress. However, the areas were still dominated by red spruce regeneration and did have a white spruce component before Hurricane Juan (Jotcham et al 1992).

In the survey conducted by LeHave Forestry Consultants Ltd (1984), most of the regeneration in Point Pleasant Park was scattered (1-500 stems/ha) or understocked (500-1200 stems/ha). The coniferous regeneration observed in the entire sample area of this study was adequately stocked (1200-4200 stems/ha), but was overstocked in strata G, H, X, and Y and understocked in strata J and W.

Exotic Species

Urban forest ecosystems are often isolated from adjacent seed sources that exist in native forests. Also, they are subject to seed dispersal from many exotic tree species found in the urban environment, which may inhibit the growth of native species (Nowak 1994, Dwyer et al 2003, Moola & Vasseur 2004). It has been found that stand-replacing events, such as hurricanes, can lead to greater invasion of exotic species in the AFR, which are often shade-intolerant pioneer species that favour disturbed conditions (Mosseler et al 2003, Moola & Vasseur 2004). There is also concern that forest fragmentation due to trails and the existing presence of exotic species in Point Pleasant Park could lead to the continued invasion of exotics, as trails can act as vectors for invasive species into native plant communities (Neily et al 2004, Keys 2005, Burley et al 2007).

The exotic coniferous species found in this study included douglas fir, scots pine, austrian pine, and possibly norway spruce. Exotic species were present at a higher density and frequency in areas with lower total regeneration, but had lower density in some areas in comparison to pre-disturbance conditions (Jotcham et al 1992). Burley et al (2007) found no significant relationship between disturbed areas and the distribution of exotic species and also found them to be present mainly in areas with better soil conditions. Native species appear to be able to out-compete exotics in the acidic, shallow soils found in Point Pleasant Park (Jotcham et al 1992, Burley et al 2007). Exotic conifers found in the sample area were all present before Hurricane Juan (LeHave Forestry Consutlants Ltd 1984, Jotcham et al 1992) and are unlikely to inhibit existing advanced regeneration in the park. However, they may impede regeneration in more disturbed areas of the sample area with less dense regeneration, especially in the centre of stratum F where exotics, mainly scots pine, constituted much of the observed regeneration.

Pre-Disturbance Survey Comparison

Natural succession in forests is highly variable and a great deal of the post-disturbance vegetation composition relies on chance (White 1991). Larger, stand-replacing gaps tend to favour the succession of shade-intolerant, short-lived pioneer species, while smaller gaps tend to be replaced by existing canopy species (White 1991, Goldblum 1997, Mosseler et al 2003). When high amounts of existing vegetation remain intact after a disturbance, the species composition of succession should resemble that of the pre-disturbance state

(Roberts 2004). It has been shown that succession following a large stand-replacing wind disturbance may also be strongly influenced by undisturbed, understorey vegetation, as well as the level of soil disturbance, more specifically, exposed mineral soil (Carlton & Bazzaz 1998, Castelli et al 1999, Burley et al 2007).

It is highly advantageous when post-disturbance regeneration studies have existing pre-disturbance vegetation surveys of the sample area to use in comparison and evaluate to what extent pre-disturbance forest structure dictates succession. Due to the management history of Point Pleasant Park, there are several vegetation surveys available for comparison (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992, Neily et al 2004).

It is possible that following a large wind disturbance event, succession will consist of a reorganization of existing canopy species, with relatively little regeneration of pioneer species, regardless of gap size (Castelli et al 1999). Mature to overmature forests, such as the majority of stands in Point Pleasant Park, will also likely have depleted pioneer seed banks. Succession following large-scale wind disturbances is dictated by seed sources from neighbouring vegetation, surviving vegetation within the disturbed area, and seed banks within the soil (Frelich 2002, Burley et al 2007). Spruce seeds have a short lifespan within the seed bank (Burley et al 2007) so the dominance of red spruce regeneration within most of the sample area must be due to neighbouring spruce within the park and surviving vegetation in the disturbed area. Area 2 is described by LeHave Forestry Consultants Ltd (1984) as having a thick red spruce understorey beneath the dominant/co-dominant white pine/red spruce overstorey. The comparison between disturbed and intact plots carried out by Burley et al (2007) found no significant difference in understorey composition. The presence of both the red spruce understorey and the immature surviving red spruce stand located in stratum X is most likely the major seed source for the park and could explain the dominance of advanced red spruce regeneration observed in this study.

In pre-disturbance conditions, there was a considerable white spruce constituent in the southeast corner of the park, especially area 8 where 61% of the observed coniferous species were white spruce (Jotcham et al 1992). The majority of area 8 is in stratum J; and while stratum J was found to have the highest concentration of white spruce in the park at 96 stems/ha (11% of the total), red spruce is still the dominant regenerating conifer. In area 8, white spruce decreased from 702 stems/ha in the pre-disturbance conditions to 89 stems/ha in this study.

Area 5 showed a drastic change in species composition since Hurricane Juan. The only coniferous species found in the area before the hurricane was red pine, which was not found during this survey. Considering the level and age of coniferous regeneration in the area, it is possible that there was an error in the Jotcham et al (1992) survey. European beech was the other dominant pre-disturbance species, but was not included in this survey. Red spruce and balsam fir were the main post-disturbance species, though total regeneration in area 5 was low, at 367 stems/ha.

It is difficult to discern the full pattern of succession in Point Pleasant Park given that only coniferous species were sampled. Burley et al. (2007) found substantial broadleaf regeneration in the park, mainly red maple and white birch. However, the observed regeneration in the park remains dominated by red spruce, as it was before Hurricane Juan. There is a substantial increase in balsam fir from pre-disturbance conditions, but the Jotcham et al (1992) survey did not tally stems below 1 m in height. The majority of observed balsam fir was 10-30 cm in height; this may explain some of the observed increases in density from pre-disturbance conditions.

Post-Disturbance Survey Comparison

The VT9 *Red spruce-Hemlock, Starflower* vegetation type is dominated by red spruce, with a hemlock-white pine component, and is a climax community. There is also a smaller white birch, red maple, and balsam fir component (Neily et al 2004). Much of the canopy remained intact in this area following the hurricane, which was likely the seed source for the hemlock found in this area. Balsam fir is highly shade-tolerant, and is typically a pioneer species found in disturbed areas (Galipeau et al 1997, Mosseler et al 2003). The dominance of balsam fir regeneration in this area was not unusual, though balsam fir is not as favourable as red spruce for regeneration because it is shorter lived and not a dominant climax canopy species (Jotcham et al 1992, Loo & Yves 2003, Mosseler et al 2003). This finding also indicated a presence of balsam fir regeneration in the understorey prior to the hurricane, as balsam fir has limited dispersal capabilities.

VT10 *Red spruce-White pine, Bracken* is also a climax community dominated by red spruce, with white pine, red maple, and balsam fir. Unit 2 contained disturbed field patches that were occasionally reverting to white-spruce-dominated patches before Hurricane Juan (Neily et al 2004). Both units of the VT10 vegetation type showed a similar regeneration pattern that is consistent with the majority of the sample area, with approximately 60% red spruce, 20% balsam fir, and a lesser occurrence of white pine, eastern hemlock, and exotic species. However, the regeneration density in unit 2 was considerably lower than in unit 1, at 1252 stems/ha versus 3721 stems/ha. This may be due to the presence of disturbed field patches that characterize unit 2, and the presence of european beech and the heather patch. White spruce was more prevalent in unit 2 than unit 1, which is indicative of the higher disturbance levels expected in unit 2 (Galipeau et al 1997, Mosseler et al 2003, Neily et al 2004).

VT11 *Red spruce-Balsam fir, Schreber's moss* is the only mid-successional community described by Neily et al (2004), and is dominated by red spruce and balsam fir, with several early successional non-coniferous species. Unit 1 was a mature stand, and sustained almost complete canopy removal from Hurricane Juan. Unit 1 was found to have a low regeneration density of 833 stems/ha, though the area remained dominated by red spruce and balsam fir. The higher densities of white spruce and exotic species than the other overlapping vegetation types could be indicative of high levels of disturbance (Mosseler et al 2003, Moola & Vasseur 2004). Unit 2 was mainly occupied by the surviving immature red spruce stand. The few plots that did lie in this unit are directly adjacent to the stand and skew the data toward dense regeneration (5538 stems/ha). Neily et al (2004) argued that the VT11 vegetation type has the potential to mature into a red spruce-white pine-eastern hemlock climax community. Considerable attention should be given to this location when deciding park management goals due to both low observed regeneration and Acadian old-growth potential.

Park Management Recommendations

Stand-initiating disturbances such as hurricanes can alter forest communities in such a way that they take hundreds of years to return to a state similar to pre-hurricane conditions (Boose et al 2001, Mosseler at al. 2003). Park managers and visitors alike hope to see relatively quick regeneration to a forest structure similar to native Acadian old growth, as it was prior to Hurricane Juan (Keys 2005, PPPIDC 2005).

Several management techniques may be possible in achieve this goal, given the findings of this regeneration survey. The first is the use of overly dense plots as donor sites for seedling transplantation to understocked areas. Slow tree growth rates have been observed in Point Pleasant Park before Hurricane Juan and thinning was previously suggested (LeHave Forestry Consultants Ltd 1984), as individual tree growth is a function of density. It is encouraging that red spruce regeneration was prevalent throughout the park, so it is important to ensure adequate growth of the species. Areas in the park that were considered overstocked, such as strata G, H, X, and Y, could act as donor sites of red spruce for strata that were understocked, such as strata J, K, and W. This transplantation would also thin the overstocked red spruce regeneration to promote faster and healthier individual tree growth.

The import of favourable conifer species, such as white pine and eastern hemlock, from nurseries for fill-planting in the park, especially the most disturbed areas of the sample area, such as strata K, J, and W, would further aid park regrowth into a healthy red spruce-white pine-eastern hemlock climax community. Planting initiatives have been successful in the park in the past, and in fact a small number of the observed seedlings may have been planted prior to Hurricane Juan. Many of the areas with the lowest observed regeneration, such as VT11, are believed to have the potential to return to a red spruce-white pine-eastern hemlock climax community, despite the high disturbance levels (Neily et al 2004). Non-coniferous regeneration, especially red maple and white birch, though not included in this study, should not be overlooked. The planting of native deep-rooted non-coniferous species, especially around the shore perimeter, would help to create a wind barrier and shift the park forests to mixedwood stands that are more resistant to catastrophic wind disturbance. Non-coniferous root systems are also good nutrient sources for the park soil (PPC 1994).

Another possible management strategy is the culling of exotic species, as they can be invasive in disturbed urban ecosystems and prevent native growth (Dwyer et al 2003, Moola & Vasseur 2004). Exotic species were found to have higher densities in areas with lower total regeneration and occupied a patch in the centre of stratum F. The planting of native species in understocked areas could eliminate the chance of exotic conifer invasion, and park visitors may also find this to be a more attractive management technique than culling. It is also important to note that the exotic species observed in this study were all found prior to Hurricane Juan and were not considered a major invasive threat to the pre-disturbance community (Jotcham et al 1992). The eventual phasing out of exotic species in Point Pleasant Park would help to return the park to a more natural state, but it is unlikely that the exotic conifer species in the park pose a threat to native regeneration.

Follow-up regeneration studies will be necessary to ensure that the regeneration observed in this study continues to be adequate in the following years. Moreover, it will be necessary to monitor the efficacy of any thinning/planting that may take place. This dataset may also be useful for other future studies such the effects of edges, fragmentation, and increased off-trail traffic on park regeneration.

Natural regeneration appears to be adequate in the majority of the sample area. A combination of passive management and monitoring in the majority of the park, and red spruce transplantation and fill planting in the southeastern edge of the park could lead to the eventual regrowth of Point Pleasant Park into a stable climax community similar to native Acadian old-growth forest. Point Pleasant Park has the benefit of having a high level of community concern because of proximity to the urban core of Halifax, high recreational value, and a long and colourful history of the area. Taking advantage of this concern to establish a volunteer community program in the park, such as a transplant/replant program, would be a low-cost tactic to enhance park recovery, public involvement, and public approval.

Acknowledgements Thank you to Tarah Wright, Blair Pardy, Jeremy Lundholm, Johanna Kalkreuth, and the GIS centres at Dalhousie University and the University of Guelph.

REFERENCES

Avery TA, Burkhart H (2001) Forest Measurements. McGraw Hill, New York, NY.

Bertram H, Miller Cl, Beers TW (1982) Forest mensuration. John Wiley & Sons, New York, NY.

Boose ER, Chamberlin KE, Foster DR (2001) Landscape and regional impacts of hurricanes in New England. *Ecological Monographs* 71:27-48.

Burley S, Robinson SL, Lundholm JT (2007) Post-hurricane vegetation recovery in an urban forest. Saint-Mary's University, Halifax. Unpublished manuscript.

Burns RM, Honkala BH (1990) Silvics of North America: 1. conifers; 2. hardwoods. US Department of Agriculture, Washington DC.

Carlton GC, Bazzaz FA (1998) Resource congruence and forest following and experimental hurricane blowdown. *Ecology* 79:1305-1319.

Connell JH, Slatyer RO (1977) Mechanisms of succession in natural . communities and their role in community stability and organization. *American Naturalist* 11:1119-1144.

Dwyer JF, Nowak DJ, Noble MH (2003) Sustaining urban forests. *Journal of Arboriculture* 29:49-55.

EC (Environment Canada) (2004) Hurricane Juan: September 28 & 29, 2003. Environment Canada, Gatineau, PQ. Unpublished report.

Farrar JL (1995) Trees in Canada. Fitzhenry & Whiteside Ltd, Markham, ON.

Frelich LE (1995) Old forest in the Lake States today and before European settlement. *Natural Areas Journal* 15:157-167.

Frelich LE (2002) Forest dynamics and disturbance regimes. Cambridge University Press, Cambridge, UK.

Galipeau C, Kneeshaw D, Bergeron Y (1997) White spruce and balsam fir colonization of a site in the southeastern boreal forest as observed 68 years after fire. *Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere* 27:139-147.

Goldblum D (1997) The effect of treefall gaps on understory vegetation in New York State. *Journal of Vegetation Science* 8:125-137.

Jotcham JR, Strong KW, Marvin TK (1992) An ecological survey of Point Pleasant Park. Maricoba Incorporate & Maritime Testing Limited, NS.

Kalkreuth JM, Duinker PN (2006) Characterizing post-hurricane coarse woody debris and overstorey in Point Pleasant Park, Halifax, NS. School for Resource and Environmental Studies, Halifax, NS. Unpublished manuscript.

Keys K, Neily P, Quigley E, Stewart B (2003) Forest ecosystem classification of Nova Scotia's model forest. Natural Resources Canada - Nova Forest Alliance, Stewiacke, NS.

Keys K (2004) Ground disturbance survey for Point Pleasant Park: post-hurricane Juan clean-up. Nova Scotia Department of Natural Resources, Truro, NS.

Keys K (2005) Point Pleasant Park forest ecosystems and soils. Nova Scotia Department of Natural Resources Truro, NS.

Kitz J, Castle G (1999) Point Pleasant Park: An Illustrated History. Point Pleasant Publishing, Halifax, NS.

LaHave Forestry Consultants Ltd (1984) A forest management strategy for Point Pleasant Park. LaHave Forestry Consultants Ltd, Bridgewater, NS.

Loo J, Ives N (2003) The Acadian forest: historical condition and human impacts. *Forestry Chronicle* 79(3):462-474.

Moola FM, Vasseur L (2004) Recovery of late-seral vascular plants in a chronosequence of post-clearcut forest stands in coastal Nova Scotia, Canada. *Plant Ecology* 172(2):183-197.

Mosseler A, Lynds JA, Major JE (2003) Old-growth forests of the Acadian Forest Region. *Environmental Reviews* 11(51):47-77.

Neily P, Keys K, Quigley E (2004) Ecosystems of Point Pleasant Park. Nova Scotia Department of Natural Resources, Truro, NS.

Nowak DJ (1994) Understanding the structure of urban forests. *Journal of Forestry* 92:36–41.

PPC (Park Planning Committee) (1994) Point Pleasant Park management plan. Halifax Regional Municipality, Halifax, NS.

Pickett STA, White PS (1985) The Ecology of natural disturbance and patch dynamics. Academic Press Inc, Orlando, FA.

Point Pleasant Park (2005) About the park: the challenge. Point Pleasant Park, Halifax NS.

PPPIDC (Point Pleasant Park International Design Competition) (2005) Stage one competition brief: regenerate, restore, renew. Halifax Regional Municipality & Southwest Properties Ltd, Halifax, NS.

Roberts MR (2004) Response of the herbaceous layer to natural disturbance in North American forests. *Canadian Journal of Botany* 82(9):1273–1283.

Rowe JS (1972) Forest regions of Canada (CFS Publication No. 1300). Department of the Environment, Ottawa, ON.

Stewart BJ, Neily PD, Quigley EJ, Duke AP, Benjamin LK (2003) Selected Nova Scotia old-growth forests: age, ecology, structure, scoring. *Forestry Chronicle* 79(3):632-644.

Simmons M, Davis D, Griffiths L, Muecke A (1984) Natural History of Nova Scotia. Nova Scotia Department of Lands and Forests, Truro, NS.

Watt AS (1947) Pattern and process in the plant community. *Journal of Ecology* 35(1-2):1-22.

White AS (1991) The importance of different forms of regeneration to secondary succession in a Maine hardwood forest. *Bulletin of the Torrey Botanical Club* 118(3):303-311.

White PS (1979) Pattern, process, and natural disturbance in vegetation. *Botanical Review* 45:229-299.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 55-63

DIFFERENTIATION OF TWO MYOTIS SPECIES (CHIROPTERA: VESPERTILIONIDAE) AT HAYES CAVE, NOVA SCOTIA, BASED ON ECHOLOCATION CALL CHARACTERISTICS

JOSEPH A. POISSANT and HUGH G. BRODERS*
Department of Biology
Saint Mary's University, 923 Robie Street
Halifax, Nova Scotia B3H 3C3

ABSTRACT

Subtle variation in echolocation call characteristics limits identification of closely related sympatric bat species acoustically. While *Myotis septentrionalis* is a forest interior specialist and *Myotis lucifugus* is a generalist, under many circumstances echolocation call characteristics overlap. During the late summer and early fall, a large migratory event involving the Hayes Cave site in Nova Scotia allowed for assessment of echolocation call structure of the two species. We captured and recorded echolocation sequences of known species by gluing a glow stick externally between the scapulae so we could visually track and acoustically record their echolocation calls. Discriminate function analysis of call characteristics yielded a protocol which resulted in a correct species identification of 96.2% for *M. lucifugus* and 97.5% for *M. septentrionalis*.

INTRODUCTION

Worldwide, the order Chiroptera accounts for 20% of the approximately 4800 described species of mammals (Engstrom and Reid 2003). They are found everywhere on earth excluding the North and South poles, and their ability to fly enables them to occupy a wide range of ecotypes. The worldwide distribution of Chiropterans has resulted in species adapted to various lifestyles in terms of food preference. For instance, megabats typically subsist on fruit and nectar (Dumont and O'Neal 2004) and are important agents of pollination (Kress 1985) but the majority of echolocating microbats consume insects (Whitaker 2004). They use their ability to echolocate to orient themselves in space and to capture prey (Kalko and Schnitzler 1993). The echolocation call characteristics of a bat will vary depending upon the characteristics of the location (e.g., amount of clutter) as well as behavior (searching for versus capturing prey) (Broders et al. 2004). For instance, *M. septentrionalis* are adapted to hunting for terrestrial insects within cluttered forest (Bogdanow-

---

* Corresponding author: hugh.broders@smu.ca

icz et al. 2000). As such, they use short duration calls with a wide frequency to discern prey items from background clutter (Broders et al, 2004). They are also classified as a "whispering bat" and use calls with an intensity of approximately 60 decibels at 10 cm (Fenton 1991). Conversely, *M. lucifugus* is a generalist and forages more often in less cluttered areas and uses longer duration calls with a narrow frequency range (Wund 2006). Their calls employ much higher amplitudes, typically surpassing 120 decibels, and they are classified as "shouting bats" (Fenton 1991). When flying in lower cluttered areas, *M. septentrionalis* will use a generalized call which can resemble those narrow frequency calls of *M. lucifugus* hence there is plasticity in echolocation call structure (Broders 2004).

Echolocation adaptations

As an evolutionary adaptation echolocation has permitted bats to exploit environments which are unavailable to many other predators. As individuals move quickly through cluttered environments they must identify and engage potential food items while simultaneously avoiding obstacles. Echolocation enables them to quickly differentiate between stationary objects such as trees and buildings and prey items which include Lepidopterans, Coleopterans, Dipterans and Trichopterans (Arlettaz 1996).

Echolocation is not without its drawbacks, of course. It has a short range, usually limited to a maximum of 15 meters (Fenton et al. 1995). As the frequency of a call increases, the range decreases due to greater attenuation of these calls in the atmosphere (Fenton 1991). The most effective range for a bat with a call of between 70 and 30 kHz is approximately 4 meters (Holderied and von Helversen 2003). This short range coupled with the high speed of flight means that bats must quickly infer possible prey items from background clutter and deal with them immediately.

In many areas where bat species richness can be quantified using acoustical surveys. In Nova Scotia, however, where there are only three common species, two of which are from the same genus and are quite similar morphometrically, it can be difficult to differentiate their calls visually by examining spectrographs. While habitat and prey specialization has caused interspecific variation in call parameters between *M. lucifugus* and *M. septentrionalis*, the inherent variability in call structure within and among individuals can result in similarly structured calls between both species. The sheer volume of calls that are recorded in areas of high activity means that future work could be more easily accomplished if an automated method was employed to accurately differentiate these two species. The goal of this research is to develop a protocol to identify bat species at Hayes cave, Nova Scotia based on echolocation call characteristics. Ultimately it is expected that this protocol can be used to track activity levels using passive acoustic monitoring.

METHODS

Study Site

Hayes cave is a solution cave in gypsum (Morris 1985) located near South Maitland, Nova Scotia. The cave is found within the Windsor group and is the largest known cave of what were originally seven caves that spanned from South Maitland to Windsor (Morris 1985; Moseley 1988). Hayes Cave is 340m long, 25m at its widest, and the interior of the cave is composed of several large chambers connected by a stream with a seasonally variable water level (Morris 1985). Due to its importance as Nova Scotia's largest known bat hibernaculum with an estimated winter population of more than 6000 individuals, the Department of Natural Resources acquired the land comprising the cave and surrounding area in the 1980s (Morris 1985). The Five Mile River originally kept the entrance of the cave open but due to farming, logging and a quarry in the immediate area, the course of the river has been radically altered. This change has resulted in the slow buildup of talus, choking the entrance of the cave from a size of at least 15 m^2 (Prest 1912) to approximately 1 m^2 currently (Garroway 2004). There is an alternate exit at the back which has an opening of approximately 0.25 m^2. Both entrances are used by bats.

Field methods

From 23 Aug to 30 September 2006, bats were trapped in a double frame harp trap (Austbat Research Equipment, Lower Plenty, Victoria, Australia). Trapping began at dusk and continued until activity ceased and captures stopped occurring within the trap. *Myotis* spp. were identified visually by examining the tragus. *Myotis septentrionalis* have a tragus that is typically long and thin and tapers to a sharp point, while *M. lucifugus*'s tragus is short and wider, with a visibly rounded bump facing posteriorly. Individuals of only one of the species per night had a 3.5cm glow stick in a red or green color attached dorsally with skinbond surgical adhesive (Figure 1). These marked bats were stored in a 5 liter Rubbermaid container until there was little or no bat activity at the site (usually around 02:00). Approximately 15 meters from the cave entrance on the path leading from the cave to the Five Mile River, a laptop computer (Intel 486 DX4-100MHZ) was set up with an anabat (Titley Electronics, Ballina, N.S.W., Australia) and ZCAIM connected to it for live data recording. The entire system was powered with a 7amp hour/12V battery and a DC inverter. Individual bats were released from an open hand by one individual while another oriented an ultrasonic microphone toward the bat as it flew to record the echolocation calls. When the bat's glow stick could no longer be seen, the file names of recorded sequences were written down.

Anabat call parameters

The anabat system is comprised of two parts, an ultrasonic call detecting device that detects sound between 10 and 200 kilohertz and another device (the ZCAIM, zero crossing analysis interface module) which analyzes the output and stores it. This system has been used extensively in acoustic identification of bat species (Wund 2006). The files created by the anabat system are in a format that includes the date of saving and the time (e.g., G8240138.19# is August 24th, 2006 at 1:38:19am). The file also contains the raw data regarding the call sequence which, when examined in the included analook program, displays the call graphically and includes the various call parameters (Figure 2). These parameters include:

F_{min} : The minimum frequency of the call in kilohertz

F_{max} : The maximum frequency of the call in kilohertz

F_{mean} : The area under the curve of the call divided by duration, measured in kilohertz

F_c : The characteristic frequency in kilohertz of the flattest portion of the call, also known as the body

F_k : Frequency of the knee, which is the point when the call moves from a steep slope to a lower, more constant frequency. The knee is the point at the beginning of the body, or flattest portion of the call. Measured in kilohertz.

Dur: The duration of a call, measured in milliseconds (ms).

T_c : The time in milliseconds from the beginning of the call to the point at which the characteristic frequency (F_c) is measured.

T_k: The time in milliseconds from the start of the call to the point at which the frequency of the knee (F_k) is measured.

S_1: The measure of the initial slope, in octaves per second, over the first five points in the call.

S_c: The characteristic slope, measured in octaves per second, is the slope over the flattest portion of the call, leading up to the point at which the characteristic frequency (F_c) is measured.

Sequence filtering and preparation

All sequences that consisted of only fragmented calls or had more than one bat sequence in it was omitted from further analysis. Remaining sequence files were cleaned in analook using the 'Z' key followed by manually deleting all but the unfragmented calls. The parameters of all calls from all files were input into Microsoft excel with each row of data representing a single call from an "echolocation sequence". Because echolocation sequences from the same bat were often recorded in multiple files, an additional column was incorporated to identify the individual that the call was made by. A column denoting species (0 for *M. lucifugus* and 1 for *M. septentrionalis*) was also added. The calls were assigned a random number from 1 to 100000 and sorted. To prevent pseudo-replication one call was randomly selected from each bat for analysis and these data were imported into Systat 10.

Discriminate function analysis

The statistical method used in the analysis of the call parameter data was two-group backward stepwise discriminate function analysis, performed in Systat 10 (SPSS Inc. 2000). In the past this method has been used successfully to varying degrees to differentiate between the calls of various species of bats (Biscardi et al. 2004). It was ideally suited to the project, as it is used to find variation between species based on quantitative measures, which in my case were the call parameters.

The species is the grouping variable and the quantitative measurements are the conditional variables. The goal of the stepwise method is to examine each conditional variable against the others and remove those variables which are deemed insignificant in the final classification. The end product is an equation in the format:

$$\text{Species} = a + b_1{*}x_1 + b_2{*}x_2 + \ldots + b_n{*}x_n$$

where a is a constant, b_1 to b_n are regression coefficients and x_1 to x_n are the conditional variables that significantly discriminate between the two species. Applying the equation to each line of data results in a positive or negative number; if the number is negative it has been classified as one species while a positive number is the other species.

RESULTS

During 13 nights from August 23st to September 30th, 2006, 2060 bats were trapped over 60.6 harp trapping hours. For 10 of these nights, one of the two species, *M. lucifugus* or *M. septentrionalis* was selected and had a glow stick attached dorsally for later release and recording. Thirty to 50 bats received a glow stick during each night of trapping. A total of 375 bats were tagged and had their calls recording upon release.

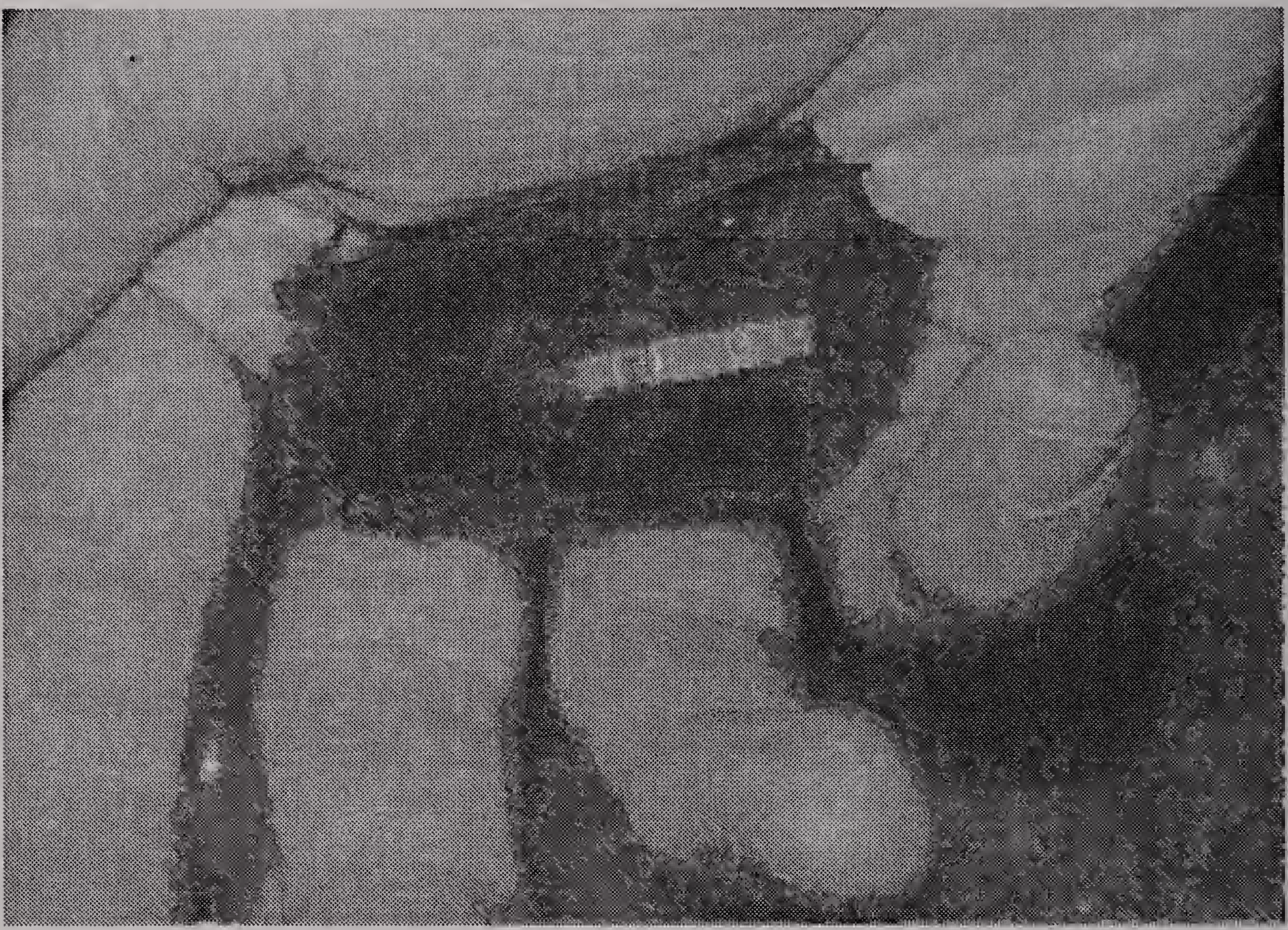
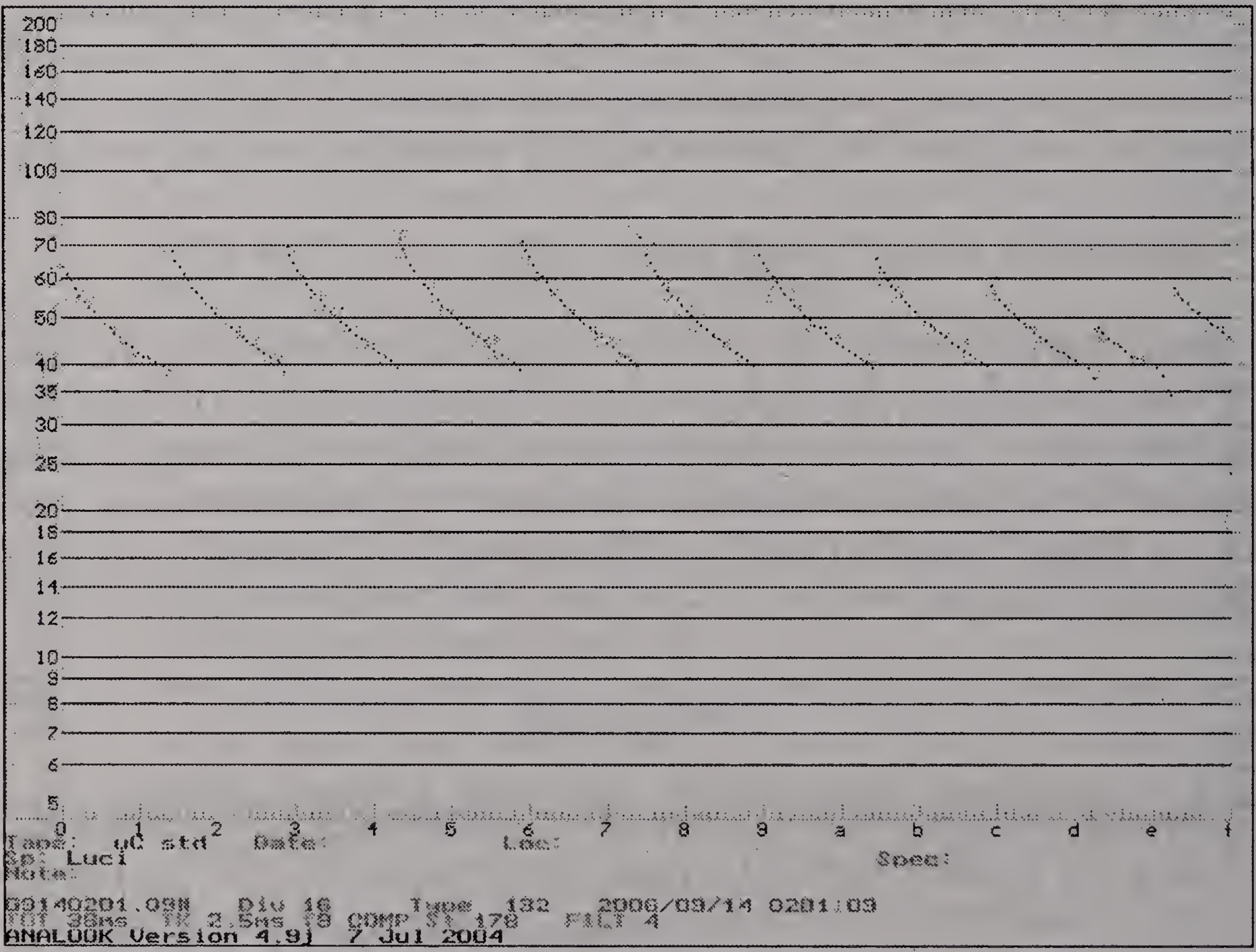


Fig 1 Northern long-eared bat (*Myotis septentrionalis*) captured at Hayes Cave (2006) with a glowstick glued to its back for tracking following release.



```
Tape:  uC std   Date:                 Loc:
Sp: Luci                                                  Spec:
Note:

09140201.09#   Div 16     Type  132   2006/09/14 0201:09
TBT 38ms  TK 2.5ms T8 COMP St 178    FILT 4
ANALOOK Version 4.9j  7 Jul 2004
```

Fig 2 Frequency-time graph from Analoook software of an echolocation sequence of the little brown bat (*Myotis lucifugus*) from Hayes Cave, NS.

Development of the protocol

A total of 923 anabat files (i.e., sequences) were recorded; 441 (48.8%) from *M. lucifugus* and 482 (52.2%) from *M. septentrionalis*. Filtering files reduced the number of files for analysis to 621: 309 (49.8%) from *M. lucifugus* and 312 (50.2%) from *M. septentrionalis*. The 621 files yielded 14674 unfragmented calls recorded from 335 bats. The backward stepwise discriminate function analysis eliminated several call parameters and determined the function:

$$\text{Group (species)} = -6.294 + (0.091 * F_{max}) + (-0.497 * T_k) + (-0.024 * F_k) + (-0.001 * S_1) + (0.004 * S_c)$$

When applied to the random call data set that determined it, the equation correctly identified all but 11 *Myotis septentrionalis* (160/171 or 93.6%) and 2 *Myotis lucifugus* (162/164 or 98.8%). When applied to the complete filtered dataset of 14674 calls, the equation correctly identified 97.5% of *Myotis septentrionalis* (5822 of 5971 calls) and 96.1% of *Myotis lucifugus* (8367 of 8703 calls). The F_{min}, F_{mean} and F_{max} of *M. lucifugus* were lower in frequency and were less spread out that those of *M. septentrionalis*. The characteristic frequency (F_c) and frequency of the knee (F_k) were also lower and showed less variation in *M. lucifugus*. Additionally, call duration showed little variation interspecifically.

DISCUSSION

As predicted, variation between the calls of *M. lucifugus* and *M. septentrionalis* around Hayes Cave enabled discrimination between the two species. Interspecific variation in call parameters in "medium" clutter at other sites correlated with several call parameters used in the determination of species at Hayes Cave; specifically, maximum frequency (Ratcliffe and Dawson 2003), initial slope, characteristic frequency and characteristic slope (Broders et al. 2004). However, a protocol to acoustically identify bat species is habitat specific; as clutter levels vary, so do the call parameters of those species (Broders et al. 2004; Wund 2005). Therefore as clutter increases it may be difficult to determine species as an individual's use of echolocation shifts from simply locating prey to also avoiding obstacles (Broders et al. 2004; Wund 2005).

The purpose of developing a protocol to determine species by call sequence is one that needs to be somewhat automated due to the large volume of sequences generated over time; unfortunately, the call sequences used to discriminate between species had to be manually filtered to achieve a reliable model. A first run through the data, without cleaning, yielded radically variable results, as the random calls selected included those which were severely fragmented, composed an echo of a call, or just background noise. These poor quality calls resulted in major error, to the point of only being able to correctly determine 70% of *M. lucifugus* and <50% of *M. septentrionalis*. Therefore, the calls of unknown origin will have to be manually filtered, at the minimum, with the 'Z' key within analook. However, sequences recording more than one bat may be retained as this data is still useful. The model was developed on a call by call basis so an individual call within a sequence still accounts for a single individual in the population.

Future considerations

Due to the safety concerns for bat researchers at hibernacula, the development of a protocol to separate calls to species was an important step toward undertaking a long term population study at Hayes Cave. Currently, this site is the largest known hibernaculum in eastern Canada and it is important to quantitatively measure the fluctuation of the population over time. In the future, it would be advantageous to systematically collect call data at specific times through the year. These times must include but may not be limited to:

1. The spring emergence, from March until the end of May
2. The fall swarming, migration and lead up to hibernation, from the beginning of August through to the end of October

It is recommended that the active trapping of bats using harp traps at least one night per week should occur during these two times to compare captures of actual individuals versus the recorded call data. The use of the call data alone is not enough to understand the population dynamics of the bats at this site; the anabat system does not discriminate between individuals and as such, it would be impossible to accurately determine how many individuals are active at the site at any given time. Therefore, the anabat data would be used to determine activity levels of species at Hayes Cave while capture data would put solid numbers to that activity level.

LITERATURE CITED

Arlettaz R (1996) Feeding behaviour and foraging strategy of free-living mouse-eared bats, *Myotis myotis* and *Myotis blythii*. *Animal Behaviour* 51:1-11.

Biscardi S, Orprecio J, Fenton MB, Tsoar A, Ratcliffe JM (2004) Data, sample sizes and statistics affect the recognition of species of bats by their echolocation calls. *Acta Chiropterologica* 6(2): 347-363.

Bogdanowicz W, Fenton MB, Daleszczyk K (2000) The relationships between echolocation calls, morphology and diet in insectivorous bats. *Journal of Zoology (London)* 247(3):381-393.

Broders HG, Findlay CS, Zheng L (2004) Effects of clutter on echolocation call structure of *Myotis septentrionalis* and *M. lucifugus*. *Journal of Mammology* 85(2):273-281.

Dumont ER, O'Neal R (2004) Food hardness and feeding behavior in Old World fruit bats (Pteropodidae). *Journal of Mammology* 85(1):8-14.

Engstrom MD, Reid FA (2003) What's in a name. *Bats Magazine*:1-5.

Fenton MB (1991) Seeing in the dark. *Bats Magazine*:9-13.

Fenton MB, Audet D, Orbrist MK, Rydell J (1995) Signal strength, timing, and self-deafening: The evolution of echolocation in bats. *Paleobiology* 21:229-242.

Garroway CJ (2004) Inter- and intraspecific temporal variation in the activity of bats at two Nova Scotia hibernacula. Saint Mary's University.

Holderied MW, von Helversen O (2003) Echolocation range and wingbeat period match in aerial-hawking bats. *Proceedings of the Royal Society of London Series B-Biological Sciences* 270(1530):2293-2299.

Kalko EKV, Schnitzler HU (1993) Plasticity in echolocation signals of European pipistrelle bats in search flight: implications for habitat use and prey detection. *Behavioral Ecology and Sociobiology* 33(6):415-428.

Kress WJ (1985) Bat pollination of an Old World heliconia. *Biotropica* 17(4):302-308.

Morris L (1985) The Hayes Cave Site, South Maitland, Nova Scotia. Curatorial Report, No. 50. Nova Scotia Museum of Natural History, Halifax, N.S., Canada.

Moseley CM (1988) The solution caves of Nova Scotia: an update. *Canadian Caver* 20:38-44.

Moseley CM (*in press*) Records of bats (Chiroptera) at caves and mines in Nova Scotia. Halifax, N.S: N.S Museum.

Prest WH (1912) Report on cave examination in Hants County, Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 13:87-94.

Ratcliffe JM, Dawson JW (2003) Behavioural flexibility: the little brown bat, *Myotis lucifugus*, and the northern long-eared bat, *M. septentrionalis*, both glean and hawk prey. *Animal Behaviour* 66:847–856.

Whitaker JO, Jr. (2004) Prey selection in a temperate zone insectivorous bat community. *Journal of Mammology* 85(3):460-469.

Wund MA (2005) Learning and the development of habitat-specific bat echolocation. *Animal Behaviour* 70:441-450.

Wund MA (2006) Variation in the echolocation calls of little brown bats (*Myotis lucifugus*) in response to different habitats. *American Midland Naturalist* 156(1):99-108.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 64-88

TWO SHARK SPECIES INVOLVED IN PREDATION ON SEALS AT SABLE ISLAND, NOVA SCOTIA, CANADA

ZOE N LUCAS[1]* and LISA J NATANSON[2]
[1] *P.O. Box 64, Halifax CRO*
Halifax, Nova Scotia B3J 2L4, Canada

[2] *National Marine Fisheries Service*
Northeast Fisheries Science Center, NOAA
28 Tarzwell Drive, Narragansett, RI 02882-1199, USA

Between 1993 and 2001, 4906 seal corpses bearing wounds likely inflicted by sharks were examined on Sable Island, Canada. Five seal species were involved: grey (*Halichoerus grypus*), harp (*Pagophilus groenlandica*), harbour (*Phoca vitulina*), hooded (*Cystophora cristata*), and ringed (*Phoca hispida*) seals. Flesh wounds on seal corpses indicated that two or more shark species prey on seals in waters around Sable Island. Wounds were categorized as either slash or corkscrew, with different predators identified for each type. Wound patterns, tooth fragments, and marks on bones indicated that white sharks (*Carcharodon carcharias*) were involved in the slash wounds, which comprised a small proportion of attacks. Ninety-eight percent of seal corpses, however, bore the corkscrew wounds that could not be attributed to shark species identified in attacks on pinnipeds in other regions and these wounds are previously unreported in the literature. Circumstantial evidence indicates that attacks by Greenland sharks (*Somniosus microcephalus*) were responsible for the clean-edged encircling corkscrew wounds seen on seal corpses washed ashore on Sable Island.

KEY WORDS: Shark Seal, Sable Island, Greenland shark, *Somniosus microcephalus* predation

INTRODUCTION

Shark predation on pinnipeds is well documented for the waters off South Africa (Ebert 1991), Australia (Shaughnessy et al. 2007), Hawaii (Hiruki et al. 1993, Lowe et al. 1996), and California (Ainley et al. 1985). White *Carcharodon carcharias* and tiger *Galeocerdo cuvier* sharks are the species most often involved. Shark predation on pinnipeds in northern waters has been seldom noted. Although shark predation has been suggested as a possible cause of the decline in harbour seals *Phoca vitulina* in Alaska (Taggart et al. 2005), there is no direct evidence of shark predation on any pinniped species in Alaskan waters (K. Goldman 2006 pers. comm.). Where shark predation on northern pinnipeds has been mentioned, species of the genus *Somniosus* (sleeper sharks) are most often

---

* Correspondence authors: zoelucas@greenhorsesociety.com and lisa.natanson@noaa.gov

suspected (Popov 1982). Shark predation on seals near Sable Island was reported by Brodie & Beck (1983) and Lucas & Stobo (2000), however the shark species involved were not identified.

Sable Island, located at the outer edge of the continental shelf approximately 160 km southeast of mainland Nova Scotia, Canada, is a breeding and pupping ground for harbour seals (Bowen et al. 2003a), and is now the world's largest grey seal *Halichoerus grypus* breeding colony (Bowen et al. 2003b). Prior to the early 1990s, shark predation on seals near Sable was sporadic (Brodie & Beck 1983). An increase in predation was first noted in January 1993 (Lucas & Stobo 2000). During 1993-1997 shark predation accounted for high mortality in harbour seals, particularly adult females and pups, and was partly responsible for a marked decline in harbour seal pup production on Sable Island (Lucas & Stobo 2000).

Our objectives here were to document shark-inflicted wounds observed on seals on Sable Island between 1993 and 2001, and to determine which shark species were responsible for the wounds.

MATERIALS AND METHODS

Sable Island, off the coast of Nova Scotia at 44°N, 60°W, is 45km long and <1.5km wide with long uninterrupted sand beaches on both the north and south sides (Fig 1). The west and east ends of the island come to a point and curve northwards. Maximum elevation is 30m, but most areas of the island are only 5-15m above sea level.

Beach searches for corpses were conducted year-round during January 1993 to December 2001 by the first author who was resident on the island. In this report, "corpse" refers to dead seals bearing wounds presumed to be inflicted by sharks. We did not observe the attacks nor were we able to recover physical evidence (such as teeth) that could confirm the predator involved in all cases. The number of search days per year averaged 154, with an overall monthly mean of 12.8 days. The fewest search days per month were in March (mean = 9.4), November (mean = 3.6) and December (mean = 6.6) because of weather and beach conditions. Although the search effort was uneven, the persistence of marked corpses on the beach (e.g. Lucas & Daoust 2002) indicated that varying length of intervals between surveys had little impact on monthly number of corpses found. Data recorded for seal corpses included number, species, age class, date, wound characteristics and amount of tissue missing from the corpse. Missing tissue was recorded as a percentage of the body surface area of the corpse. Age was categorized as pup, immature and adult, and was determined on the basis of one or more of the following variables: size (standard

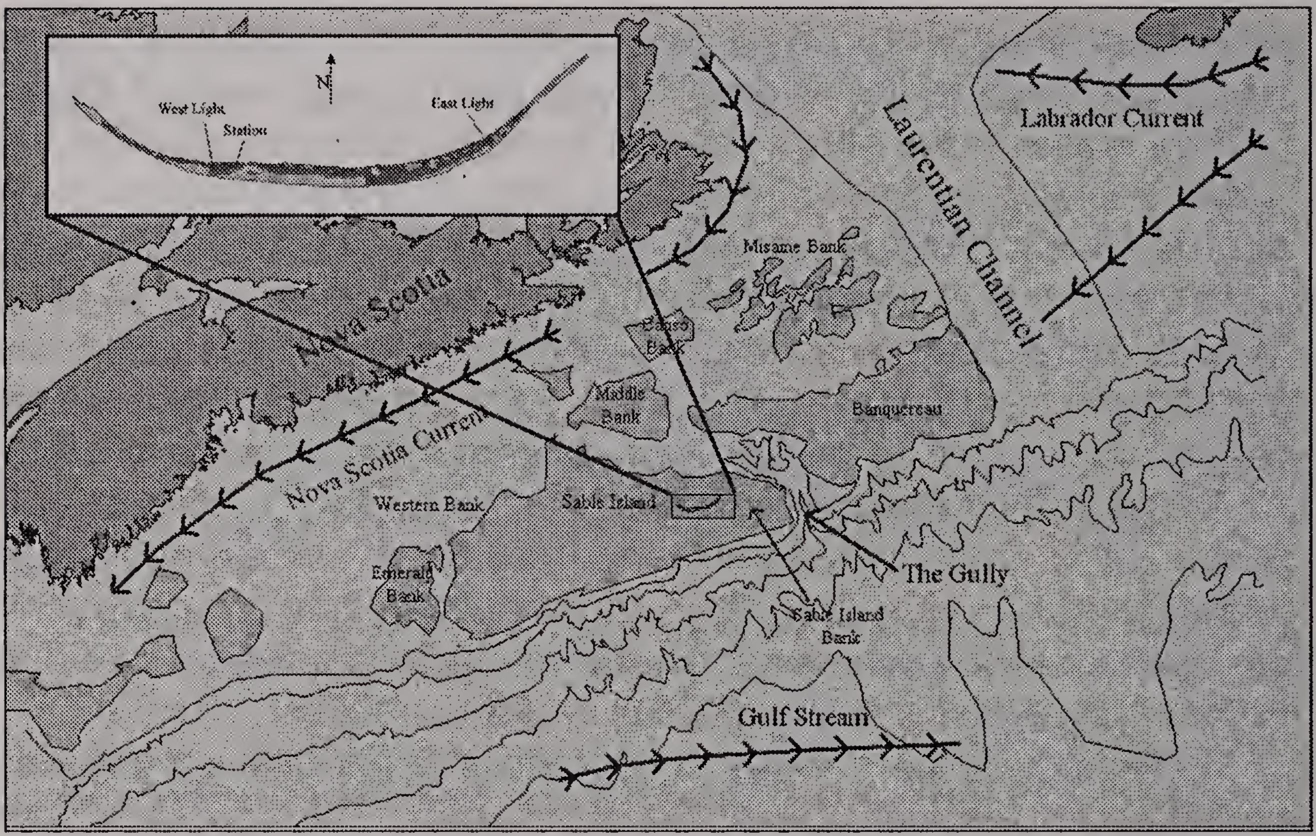


Fig 1 Nova Scotia and Sable Island, Canada

length, McLaren 1993); presence of lanugo; pelage pattern, colour and wear; and tags or brands applied by researchers with Fisheries and Oceans Canada. Month of death used in reporting results and analyses was estimated based on degree of scavenging and decomposition (e.g. a partly decomposed corpse washed ashore in the first week of June was considered a May kill).

Wounds were categorized as either slash or corkscrew. The slash wound comprised one or a combination of cuts, punctures and rake marks, on any part of the body, often in a pattern suggesting a bite (Fig 2). The corkscrew wound, which lacked the usual features of shark bites, was typically long and clean-edged, and always found on the front of the seal running diagonally around the body axis from the head to some point between the shoulders and pelvic areas (Figs 3 and 4).

RESULTS

A total of 4906 seal corpses of five species were found on Sable Island during 1993-2001, of which grey seals comprised 76%, and harp *Pagophilus groenlandica*, harbour and hooded *Cystophora cristata* seals comprised 13%, 9% and 1%, respectively. One ringed seal *Phoca hispida* corpse was recovered. The numbers of presumed shark-killed seals reported here are minimums. It is not known what proportion of corpses were unrecorded because they were entirely consumed by the attacking sharks, or the corpse was

Table 1a Numbers of seal corpses found by species and age with a) slash wounds, and b) corkscrew wounds.

Species	Age group	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Grey seal	adult		1	2	3		6		1		13
	immature	2	2	1		3	3	3	2	4	20
	pup		14	8	8	16	13	5	13	9	86
Harbour seal	pup	2	1								3
Total		4	18	11	11	19	22	8	16	13	122

Table 1b

Species	Age group	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Grey seal	immature	1	2	284	2	20	9	23	10	17	368
	pup	65	127	7	360	543	558	579	490	529	3258
Harbour seal	adult	12	51	73	57	31	9	1	7	4	245
	immature	1	12	5	5	1					24
	pup	16	71	42	39	13	1	2		1	185
Total		95	263	411	463	608	577	605	507	551	4080

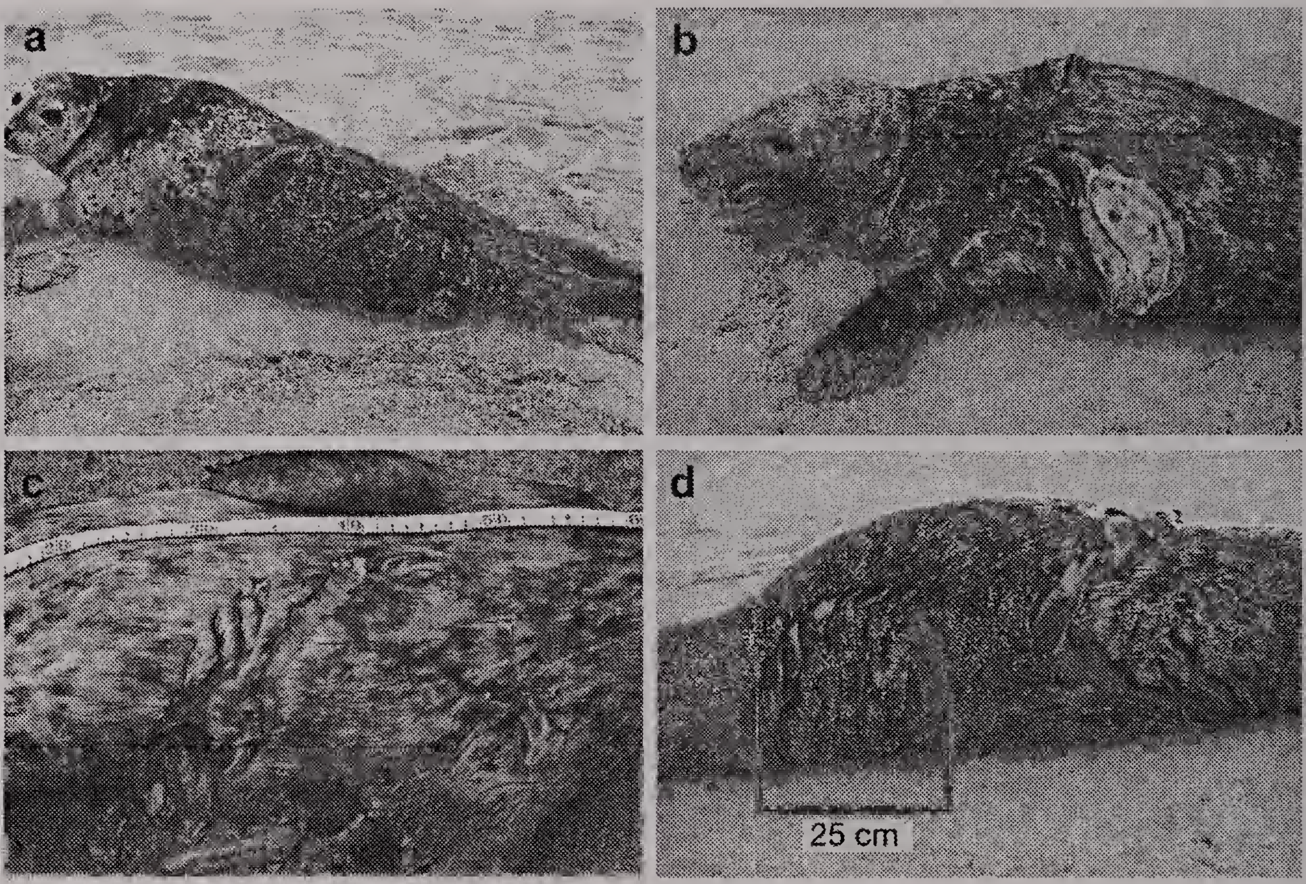


Fig 2 Slash wounds on Sable Island seals

a) An adult harbour seal with slash wounds on back, hip and rump.
b) A juvenile grey seal with wounds on back and shoulders. No tissue is missing. Elasticity in the skin causes the wound edges to pull apart, exposing blubber beneath the skin.
c) Pectoral area of the corpse of a juvenile grey seal (right front flipper at the top of the photo). The wound, roughly 25 cm in width, shows the arc of the bite.
d) The left side of a juvenile grey seal corpse, (shoulder, upper back, and hip). The seal had been bitten at least three times.

not beached or was completely decomposed and/or scavenged while still in the water. Of the 4906 corpses examined, 2% bore slash wounds, and 98% bore corkscrew wounds. For description of wound characteristics and identification of the predator we used observations collected from the island's two breeding species, grey and harbour seals. The other three seal species will not be considered further in this paper.

Slash wounds

Slash wounds (Table 1a and Fig 2) ranged in severity from several score marks and superficial punctures on the hide, to one or more extensive deep cuts. Over 90% of these seals were injured in more than one of the five positions on the body (Table 2), with 31% injured in at least four of the body positions. Fifty-two percent of all wounds were on the hindquarters. The pattern of some slash wounds suggested the arc of teeth in one or both jaws of the attacking shark (Figs 2c and 2d). Where an arc could be discerned and measured,

Table 2 Position of slash injuries attributed to white sharks on 114 corpses (3 harbour seals and 111 grey seals) at Sable Island between 1993 and 2001.

Location of wound on seal's body	Number of records	Percent of 349 location records	Percent of 114 seals*
Head, neck	15	4.3	13.2
Shoulder, chest, foreflippers	64	18.3	56.1
Trunk	88	25.2	77.2
Rump, hips, pelvis	92	26.4	80.7
Tail, hind flippers	90	25.8	78.9
Total	349	100.0	

* The sum of the records expressed as a percentage of 114 seals exceeds 100% because many seals had wounds on more than one part of the body.

bite width ranged from 25-35cm. In 86% of corpses, no tissue was missing, and only one, a female adult grey seal, had lost a limb.

Most (99%) of the corpses with slash wounds were observed during July through October, with 44% found in August. Only one slash-wounded corpse was found in June; none were found in November through May. Seventy-three percent of corpses with slash wounds were pups (Table 1a). Although few corpses were examined for score marks on bone and tooth fragments, a tooth fragment identified as shortfin mako (D. Long 1996 pers. comm.), was found embedded in a hind limb bone that was also scored by white shark teeth. Fragments and score marks of white shark teeth were found on the bones of two other corpses (D. Long 1996 pers. comm.).

Although it was impossible to determine how far offshore seals were attacked, there were indications that some seals had been attacked close to the beach. On several occasions live wounded seals were observed coming ashore with arterial blood spurting from wounds.

Corkscrew wounds

Corkscrew wounds (Fig 3) were recorded for 3626 grey seals and 454 harbour seals (Table 1b and Fig 5). Although corpses bearing fresh corkscrew injuries occurred throughout the year (Fig 6), there was a significant difference in numbers per month for both grey $\chi 2(11, N = 3626) = 3127.1, p = 0<0.05$) and harbour seals $\chi 2(11, N = 454) = 209.5, p = 0<0.05$). Seventy-nine percent of grey seals were found in January and February, while most (88%) of the harbour seals were found in April through September peaking in June.

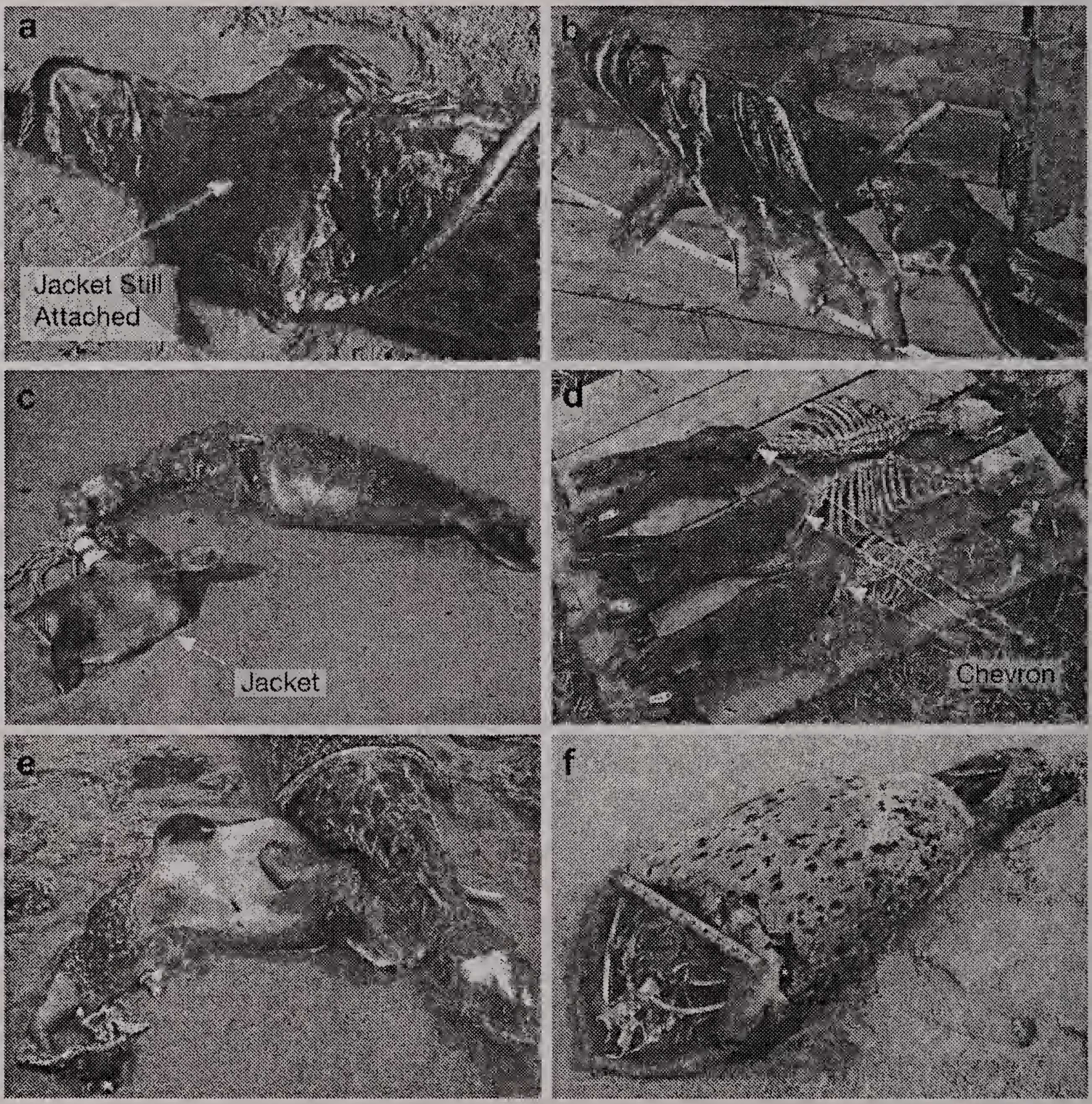


Fig 3 Corkscrew wounds on Sable Island seals

a) Ventral view of the upper body of a juvenile grey seal. The wound runs between chin and pectoral area in a counterclockwise path across the throat and around to just below the right front flipper. No tissue is missing.

b) Dorsal view of a harbour seal pup. Parallel tears run in a counterclockwise direction around the body, showing the lighter-coloured ventral pelage at the end of each strip. Such complex wound patterns were seen most often in harbour seal pups. No tissue is missing.

c) The right and left front flippers and scapulas (jacket), have been removed from the upper body of an adult harbour seal, but remain attached by a strip of skin on the snout. A chevron is present on the corpse's back. No tissue is missing.

d) Three harbour seal pups with jackets missing. Although gulls have scavenged soft tissues, the spine and ribcage in each corpse is intact, and except for the jacket, the skeleton is complete. With further scavenging and decomposition, the remaining connective tissue ceases to hold the corpse together.

e) An adult harbour seal with the jacket attached to the body by a shred of tissue at the right scapula. The jacket includes the snout (nostrils and vibrissae, in the lower left corner), and the alternating light ventral and dark dorsal pelage shows how the fragment came off in a helical tear around the body. When fitted to the body, the fragment indicates a counterclockwise path.

f) Ventral view of the lower half of an adult harbour seal showing the chevron wound edge pattern on the dorsal surface. In the past, such corpses were described as being "bitten in half by a white shark", however, the clean-edged chevron is diagnostic of a jacket removal, and confirms that the partial corpse is a remnant of the corkscrew kill.

All grey seal corpses were young animals, with pups comprising 89.9% of the total. However, in harbour seals, the majority of corpses were adults (Table 1b).

The fresh condition of some seal corpses indicated that they had washed ashore within a few hours of being killed and thus had been attacked close to the beach. Several were still bleeding and had a core temperature that was warm to the bare hand.

All corkscrew wounds were so clean-edged that they appeared to have been made with a sharp instrument. The wound typically penetrated hide and blubber, but did not cut into muscle tissue. Although the bones of face and jaws were sometimes fractured, other skeletal material, trachea, and organs were most often intact (except for damage caused by scavenging gulls). The lack of skeletal damage was evident even in the harbour seal pups, the smallest and most delicate of seal corpses (Fig 3d). Punctures in tissue, if present, were usually small and found on the face. In most corpses in which the head was not lost, the facial-mask (the area between forehead, ears and nostrils) was undamaged. Fresh specimens, before scavengers and decomposition removed tissue and organs, looked skinned (Figs 3c and 3e). In highly scavenged and partly decomposed corpses, corkscrew wounds could be identified on the basis of several characteristics, including the presence of strips of hide showing alternating dorsal and ventral pelage patterns (Fig 3e), which indicated that the strip had encircled the body, and the presence of a chevron-shaped contour along one edge of the remaining tissue (Figs 3d, 4b and 4c).

In July 1994, the carcass of a freshly killed harbour seal pup bearing a time-depth recorder (TDR) was washed ashore. The TDR had been applied by researchers studying diving and foraging behaviour (Bowen et al. 1999). A typical corkscrew wound encircled the body, but its path was unaffected by the presence of a large section of nylon webbing, glued with epoxy to the coat on the seal's back, which served as a mount for the TDR. The webbing, epoxy, and acrylic casing of the instrument were not damaged and showed no sign of having been bitten (i.e. no scratches or punctures), yet the wound ran through the tissue under the webbing. Tissue at one

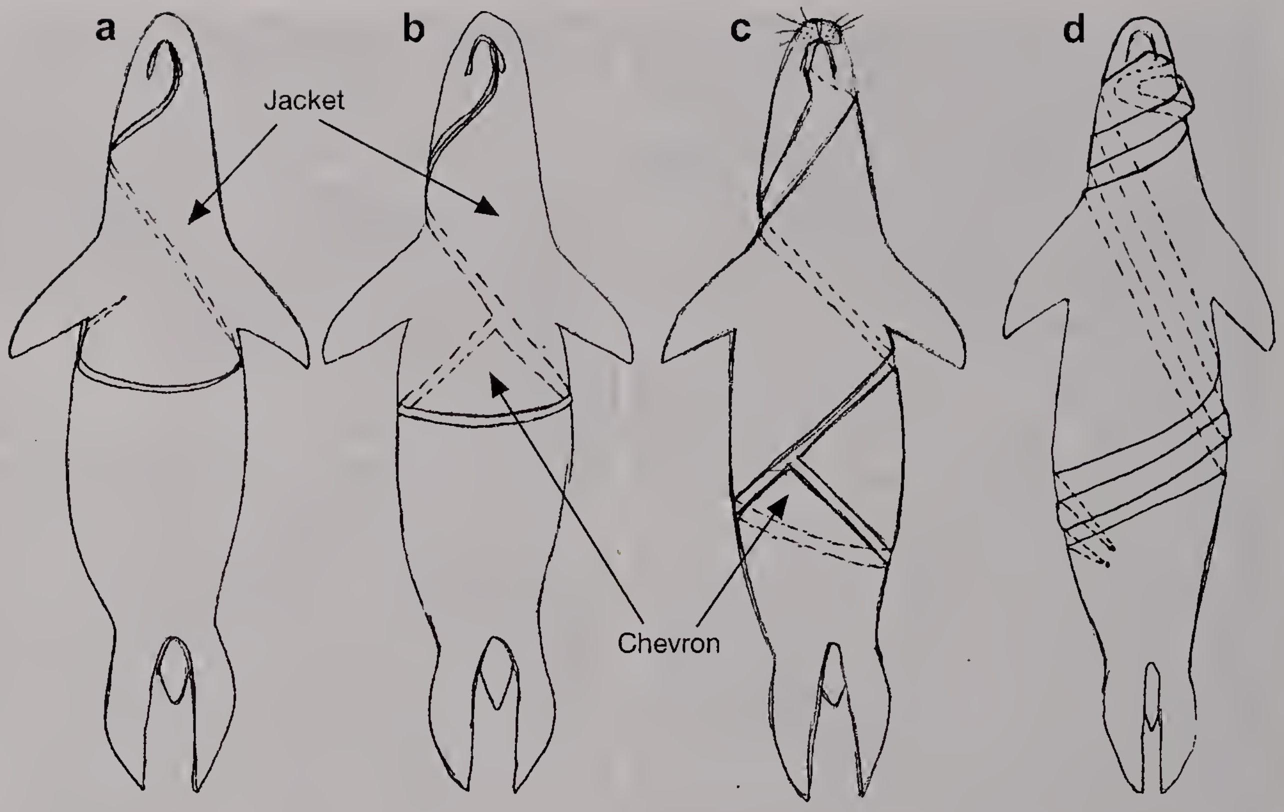


Fig 4 Diagrams of counterclockwise corkscrew wounds on seal corpses found at Sable Island. All are ventral views.

a) The wound runs around the body in a helical path between the left jaw and the right side of the upper back, similar to the wound path shown in Fig 3a.

b) The wound intersects on the upper back, and is similar to the wound in Fig 3c. Although the skin is still attached to the chin and right lower jaw, with such a "completed" tear, the jacket and blubber layer can be torn away from the body. The wound forms the characteristic chevron on the seal's back.

c) A long single tear line runs around the body twice and intersects on pelvic area of the seal. Ventral chevrons are most often formed by tears that encircle the body two or more times.

d) Parallel tears run around the body but do not intersect. This wound pattern is similar to that shown in Fig 3b.

side of the wound had pulled away from the webbing, indicating that the tissue had been torn, not cut.

Of the 1119 corpses examined for missing tissue, 61% had ≤5% missing. In 53% of the complete corpses examined for wound pattern (924), the corkscrew wound was almost identical: a long, single tear line with no tissue missing (Figs 3a, 4a and 4b). The remaining 47% of complete corpses bore wounds comprised of two or more parallel tears (Figs 3b and 4d) sometimes with a small patch or strip of tissue missing from the face or neck. In the incomplete corpses missing tissue ranged from strips of hide and blubber, to the entire front half or front three-quarters of the body (i.e. all tissue and skeletal material). Most often the missing tissue was a jacket, the section of hide and blubber from the front half of the body, with

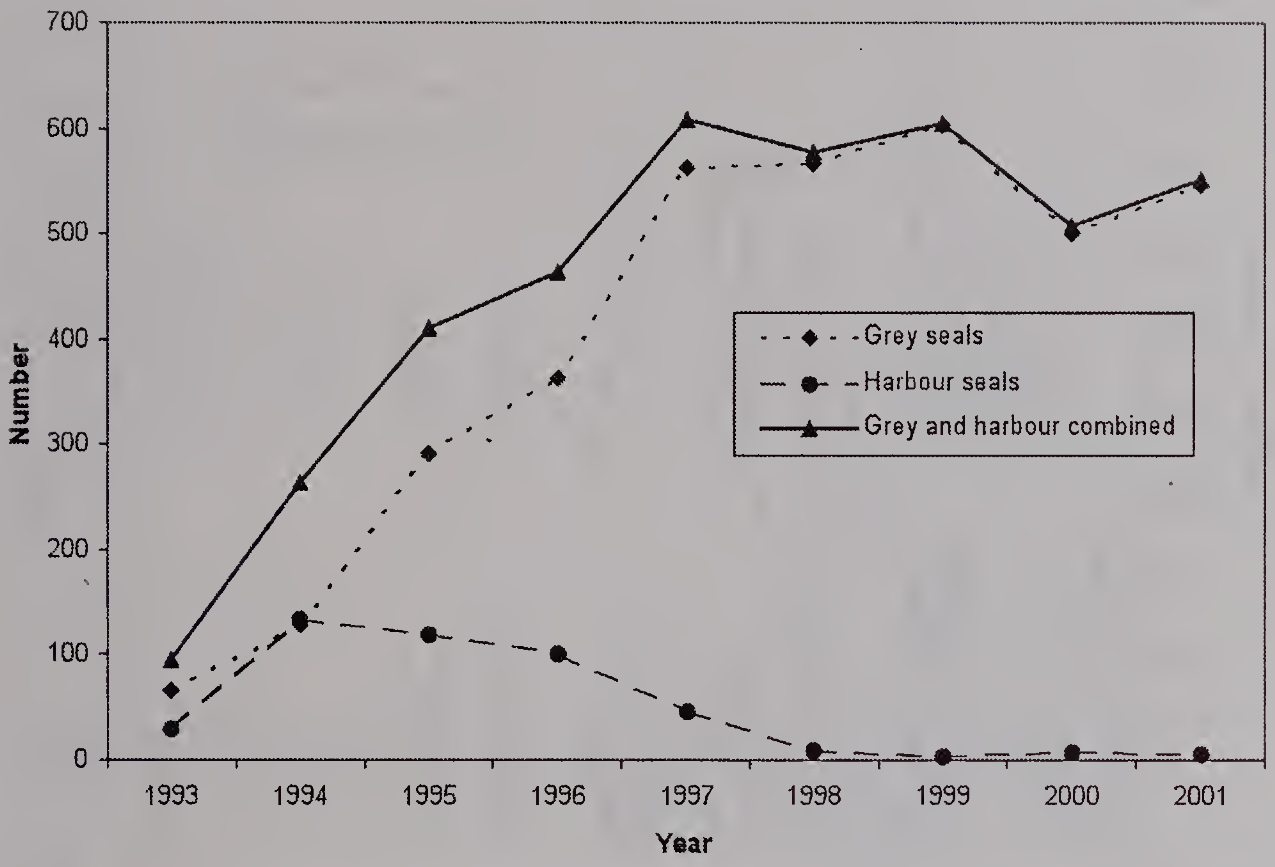


Fig 5 Number of seal corpses with corkscrew wounds by year

both front flippers, and usually scapulas, attached (Figs 3c and 3d). Of the 3004 corpses for which the presence or absence of a jacket was recorded, 5.7% were missing full jackets and 3.9% were missing partial jackets (with only the left or right flipper and scapula). A chevron was present in 39% of the 1314 corpses for which the presence or absence of a chevron was recorded.

DISCUSSION

Characteristics of wounds observed on beached seal corpses indicate that at least two shark species were involved in the predation on seals near Sable Island. The majority of seal corpses bore wounds that could not be attributed to shark species previously identified in attacks on pinnipeds in other regions. Numbers of shark-killed seal corpses recovered reflected seasonal local abundance of grey and harbour seals.

Grey seals are year-round residents on Sable Island, and the island is a major breeding ground for this species (Bowen et al. 2003b). The size of the population increased during the 1980s to present, and in the latter years of the study period, grey seals produced approximately 20,000-25,000 pups during each December to February pupping season (Bowen et al. 2003b). Although large numbers of grey seals are in waters near the island throughout the year, the majority of grey seal corpses were observed in January

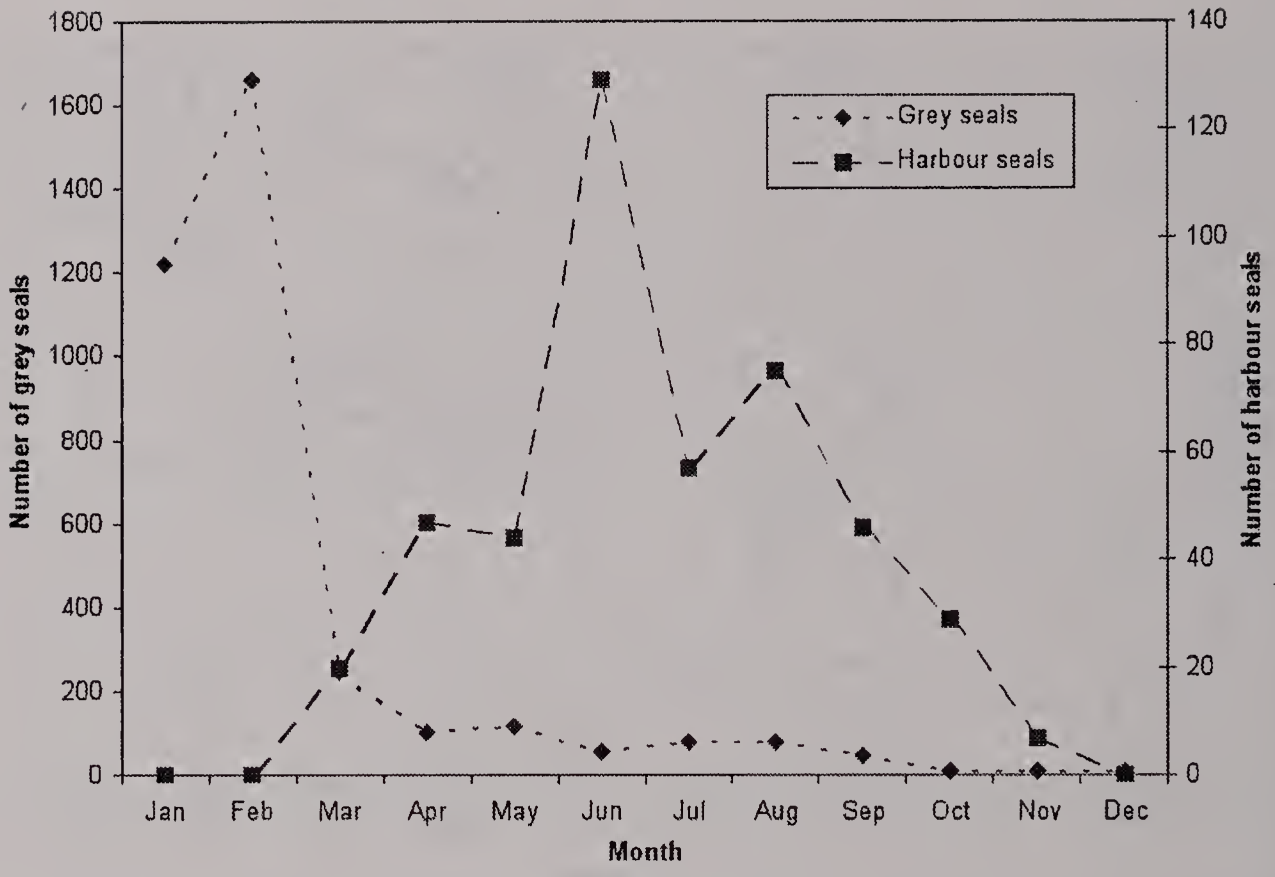


Fig 6 Number of seals corpses with corkscrew wounds by month

and February corresponding with the grey seal breeding season when recently weaned pups enter the water.

Harbour seals are also year-round residents and breed on the island, although they comprise a far smaller population than grey seals. Harbour seal adults congregate during spring and summer for pupping and breeding. At this time, nursing mothers with pups and recently weaned pups are in the water. Harbour seal pup production declined from 625 pups in 1989 to only 32 in 1997, due primarily to shark-inflicted mortality (Lucas & Stobo 2000). Thus, during the study period, harbour seals on Sable Island were outnumbered by grey seals by >20:1, increasing to >500:1 by the end of the 1990s (Bowen at al. 2003a). However, there were still 300 to 400 adult and immature harbour seals frequenting the island (W.D. Bowen 2006 pers. comm.), particularly during the annual molt in July-August.

Life history information on the various shark species that seasonally inhabit the region provides insight regarding which shark species were responsible for these attacks.

Scotian Shelf Sharks

Few shark species reside year-round in Canadian waters; however, seasonal migrants increase the species composition in the warmer months of summer (Templeman 1963). Twenty shark species have been recorded off Nova Scotia, although many have been seen infrequently (Table 3). Based on size, distribution and/or feeding ecology, 14 of the 20 species can be ruled out as having

Table 3 Information on twenty shark species reported off Nova Scotia. Species arranged by size. Shaded species are those which, based on size, seasonal distribution and feeding ecology, could be predators on Sable Island seals.

Species	Max size TL (m)	Primary distribution in the western North Atlantic	Food types	Occurrence in Nova Scotia
Rough sagre, *Etmopterus princeps*	0.75	Scotian Shelf to New Jersey	Unknown	Occasional 567-2213m
Black dogfish, *Centroscyllium fabricii*	1	Greenland to Virginia, possibly south in deep water	Invertebrates and small fish	Deepwater ~460m
Portuguese shark, *Centroscymnus coelolepis*	1	Grand Banks to Delaware Bay	Bony fish, squid	Uncommon
Atlantic sharpnose shark, *Rhizoprionodon terraenovae*	1.2	New Jersey to Florida	Bony fish and invertebrates	1 record, very rare
Spiny dogfish, *Squalus acanthias*	1.4	Greenland to Cuba	Small fish and invertebrates	Common seasonal, summer to late fall
Smooth dogfish, *Mustelus canis*	1.5	Massachusetts to Florida Uncommon north of MA	Large crustaceans, small fish	Northern limit, rare
Deepsea catshark, *Apristurus profundorum*	~1.6	Atlantic coast?	Bottom and midwater fish and invertebrates	Not uncommon, distribution unknown but deep 1300-1600m
Sand tiger, *Carcharias taurus*	3.2	Gulf of Maine to Florida, poleward migrations in summer	Bony fishes, small sharks, invertebrates	Observed rarely

Table 3 *Cont'd*

Species	Max size TL (m)	Primary distribution in the western North Atlantic	Food types	Occurrence in Nova Scotia
Oceanic whitetip, *Carcharhinus longimanus*	3.5	Maine to Argentina	Bony fish and cephalopods, mammal carrion, birds, turtles and invertebrates	Northern limit, uncommon in EEZ
Porbeagle, *Lamna nasus*	3.7	Newfoundland to New Jersey	Schooling fish and squid	Common, year round
Dusky shark, *Carcharhinus obscurus*	3.7	Cape Cod and Georges Bank to Florida	Bony and cartilaginous fish, whale meat uncommon	Northern limit, rare
Blue shark, *Prionace glauca*	3.8	Newfoundland to Argentina	Fish and squid, scavenge on marine mammal	Primarily summer but all months except January and December
Shortfin mako, *Isurus oxyrinchus*	4	Newfoundland to Brazil	Pelagic fish, including swordfish, some marine	Summer mammal
Smooth hammerhead, *Sphyrna zygaena*	4	Nova Scotia to Florida	Bony and cartilaginous fish, invertebrates	Occasional, summer only
Bluntnose six gill shark, *Hexanchus griseus*	4.8	North Carolina to Florida	Fish, invertebrates, carrion, seals	Rare, 2 juveniles collected in 1989
Thresher shark, *Alopias vulpinus*	5.5	Newfoundland to Cuba	Bony fish, squid, crustaceans	Summer to November, peak in August/September

Table 3 *Cont'd*

Species	**Max size TL (m)**	**Primary distribution in the western North Atlantic**	**Food types**	**Occurrence in Nova Scotia**
Tiger shark, *Galeocerdo cuvier*	5.5	Cape Cod, MA to Uruguay	Fish, turtles, birds, marine mammals	Probably northern limit, rare, only small specimens reported
White shark, *Carcharodon carcharias*	6.4	Newfoundland to Cuba	Fish, marine mammals	Sporadic, April-November, peak in August
Greenland shark, *Somniosus microcephalus*	6.4-7.3	Arctic to Cape Cod, further south in deeper water	Fish, marine mammal, birds, invertebrates	Reported in spring, winter and fall, deeper in summer
Basking shark, *Cetorhinus maximus*	9.8	Newfoundland to Florida	Plankton	Summer

References: Scott & Scott 1988; Compagno 1984; Joyce et al. 2002; Stillwell & Kohler 1982; Stevens 1973, 1984; Stillwell & Kohler 1982; Gilhen & Coad 1989.

caused the types of wounds observed on seals at Sable Island. While porbeagle *Lamna nasus* distribution and size suggest it as a possible predator, an extensive study on porbeagle in the area indicated no evidence of marine mammals as a food source (Joyce et al. 2002). Of the remaining six species, two, the bluntnose sixgill shark *Hexanchus griseus* and the tiger shark, have been reported in the region only as juveniles, an age group that would not normally be feeding on marine mammals (Ebert 1994, Lowe et al. 1996). The occurrence of two neonatal (60-70cm total length, TL) (Ebert 1986) bluntnose sixgill sharks in waters off Nova Scotia (Gilhen & Coad 1989), suggested the recent presence of a mature female. However, in a compilation of deepwater species caught between 38°N into the Mid-Atlantic Bight and northwards to the Scotian continental slope from the 1960s to 2002, no other members of this species have been reported (Moore et al. 2003).

Large tiger sharks are known predators of marine mammals in the Pacific (Hiruki et al. 1993, Lowe et al. 1996). Tiger sharks have been reported in waters well south of Sable Island (N. Kohler 2006 pers. comm.); however, the largest was 155cm fork length (FL), which is well below the size that usually preys on marine mammals (Lowe et al. 1996). Large tiger sharks have been captured in the Canyons off the US East Coast and it is possible that some could move into waters near the island from the offshore warmer waters during the late summer or when Gulf Stream eddies move warm water masses toward the Sable Island Bank (Zwanenburg et al. 2002). Lowe et al. (1996) suggest that tiger sharks are opportunistic feeders, thus they may migrate to take advantage of seasonally abundant prey. Despite the potential for consumption of marine mammals by large members of this species, the rarity of sightings, and the small sizes of those sighted, indicates that Nova Scotia is probably the extreme northern limit of their range and it is unlikely that a large enough population existed in the area to account for the number of attacks near Sable Island.

The four remaining species are shortfin mako, and blue, white and Greenland sharks. Diet and temperature preferences rule out the shortfin mako, blue and white sharks for the majority of the attacks that occur in January and February. Beached specimens of both blue shark and shortfin mako have been found on Sable Island during the last 20 years (Z. Lucas unpub. data). Four blue sharks were found in July, August, and late October, and two shortfin makos occurred in August and late October. Blue sharks are found in these waters during most of the year, but are infrequent or absent in December and January (Templeman 1963, Campana et al. 2006a). Shortfin makos in Atlantic Canada are generally associated with the warm waters of the Gulf Stream (Campana et al. 2006b) and are primarily reported during summer and early autumn in the Scotian Shelf region (Campana et al. 2005). The limited occurrence of marine mammal tissue in the stomach contents of blue sharks and shortfin makos worldwide (Stevens 1973, Cliff et al. 1990, Cortes 1999, Henderson et al. 2001) and specifically in the northwest Atlantic (Kohler & Stillwell 1981, Stillwell & Kohler 1982, McCord & Campana 2003) suggests that these species only consume marine mammals opportunistically and are not likely to be major predators on seals. While it is possible that these species switch prey in this area of high marine mammal concentration, the size of the bite of a slash wound, when present, was too large for the blue shark and unlike the ragged edged bite that is caused by the pointed teeth of the shortfin mako. Additionally, seasonal distribution ruled out these species for the corkscrew wounds.

White sharks are not common, but range between the Gulf of Mexico and Newfoundland (Templeman 1963, Casey & Pratt 1985). The white shark is found in temperatures of 11-24°C but most occurrences (75%) are in the range of 15-22°C (Casey & Pratt 1985). Distribution studies have indicated that the larger whites (>200cm TL) occur over the whole geographical range, whereas the smaller white sharks are more confined to the Mid-Atlantic Bight area due to a limited temperature tolerance (Casey & Pratt 1985). In the region of the Gulf of Maine and Nova Scotia, there is a peak in sightings of white sharks in the months of July and August, and these are mostly larger individuals whose primary prey are marine mammals (Casey & Pratt 1985, Estrada et al. 2006). Since 1800, only one white shark has been reported between December and June in Atlantic Canada (T. Curtis 2010 pers. comm.).

The Greenland shark *Somniosus microcephalus* is common in Arctic waters from Eurasia to North America. Cape Cod, Massachusetts in the west, and the British Isles in the east, are considered the southern extremes of its known normal range (Benz et al. 2007); however, large Greenland sharks have been caught as far south as Cape Hatteras, North Carolina (J. Casey 1994 pers. comm.). In many portions of its range, the Greenland shark is abundant and has been both target and by-catch of fisheries. Greenland sharks have been found in temperatures ranging from polar extremes up to 10-12°C (Compagno 1984). This species tracked off northern Baffin Island (Skomal & Benz 2004) showed no apparent depth or temperature preference and was found to move into shallower waters at night. Results indicated that this species is not exclusively benthic and suggested that the Greenland shark may actively hunt ringed seals under landfast sea ice (Skomal & Benz 2004).

Little is known about the migratory movements of the Greenland shark. Historically, this species is known to be in Scotian Shelf waters in autumn and winter (Templeman 1963), and has been reported on Georges Bank on the Scotian Shelf in summer (J. Conway 1996 pers. comm.). In October, there is a large increase in numbers of Greenland sharks in the northern section of the Davis Strait, and the sharks appear to be moving down from north at that time (J. Pedersen 1994 pers. comm.) The Greenland shark appears to be a generalist predator; its diet includes a wide variety of fishes and elasmobranchs (Bigelow & Schroeder 1948, Templeman 1963). Also listed as food items are seabirds, squids, crabs, large snails, medusae and entire reindeer (without horns) (Bigelow & Schroeder 1948). Greenland sharks are reported to be carrion feeders, tending to gather around whaling stations to obtain offal (Bigelow & Schroeder 1948) and entering shallow water to feed on camp garbage (Beck & Mansfield 1969).

Recent evidence indicates that the trophic level of the Greenland shark increases with size and that seals may be a common food item of some large Greenland sharks (Fisk et al. 2002, Yano et al. 2007). Yano et al. (2007) found that marine mammals (at least three species of pinniped) were the second most common prey item in terms of frequency of occurrence and index of relative importance. Whole and portions of harbour, ringed, harp and hooded seal have been found in the stomachs of Greenland shark from many locations (Bigelow & Schroeder 1948, Ridoux et al. 1998, Orlov 1999, Fisk et al. 2002, Yano et al. 2007), but it was unknown whether the seals were consumed as live prey or were scavenged. Recently, however, Yano et al. (2007) found freshly dead pinnipeds in the stomach contents of Greenland sharks, suggesting that the sharks captured active prey.

Slash wounds

Based on the seasonality of the slash wounds and the behaviour, range and temperature tolerances of the sharks in the region, the white shark and shortfin mako were the most likely species responsible for the slash wounds. In many regions, pinnipeds appear to be a major source of food for white sharks (Ainley et al. 1985, Long et al. 1996, Shaughnessy et al. 2007). Slash wounds coincided with the summer and early autumn occurrence of white sharks in the Scotian Shelf region (Casey & Pratt 1985, Casey & Kohler 1992). Additionally, the slash wounds were generally similar to injuries inflicted on seals elsewhere by white sharks (Long et al. 1996). Score marks made by white shark teeth on the bones of several fresh corpses bearing slash wounds indicated that white sharks were near Sable Island when they attacked the seals. The location of Sable Island and its use by thousands of seals makes it a likely site for large white sharks to feed during summer migration. It is hypothesized that white shark distribution is related to prey availability within thermal limits and, on the West Coast, that they time their movements to those of breeding pinnipeds (Long et al. 1996). Since Sable Island is the only consistent source of congregated prey in the region, it is likely that white sharks would utilize this food source during the months that the water temperature is in a tolerable range.

The shortfin mako tooth fragment embedded in seal bone also scored by white shark teeth, suggested that the shortfin mako may be responsible for some attacks or may be scavenging on the corpses of seals killed by white sharks. While the shortfin mako cannot be excluded as the possible cause of some of the injuries, based on wound characteristics, it is probable that most, if not all, of the slash wounds seen on seal corpses at Sable Island were inflicted by white sharks. Slash wounds were observed on grey seals of all ages indicating no prey size limitation.

Corkscrew wounds

The unusual nature of the long clean-edged corkscrew wounds, which are atypical of well documented shark-inflicted injuries, suggested causes including manmade hazards, ice, and other predators such as killer whales *Orcinus orca*. The corkscrew wounds, however, are markedly different from the wounds seen on manatees injured by ship propellers (Hare & Mead 1987), and the evidence that some kills had occurred close to the beach further rules out propellers since Sable's shoreline is not accessible to ships. Wounds also bore no similarity to entanglement injuries caused by net, rope, or strapping, all of which have been observed on Sable Island during marine litter and entanglement studies (Lucas 1992). Access to Sable Island is restricted and activities monitored, thus it is not possible that the wounds could have been deliberately inflicted by humans. Killer whales are uncommon in the Scotian Shelf region (Lucas & Hooker 2000), and the clean-edged wounds are not consistent with the dentition and feeding behaviour of these cetaceans (R. Baird 2008 pers. comm.). Pack ice does not normally occur within 200 km of Sable Island (G. Forbes 2010 pers. comm.).

Attributes of the life history of the Greenland shark suggest it was the predator causing the corkscrew wounds. The teeth of Greenland sharks are markedly dissimilar in the two jaws. The upper teeth are small and thorn-like; the lower teeth are subquadrate, about half as broad as high, each overlapping the next outermost and forming a continuous saw-like or bread knife-like cutting edge. Wound patterns found on seal corpses on Sable Island suggest that the Greenland shark grasps the live seal front first; the lower teeth cut into the hide, and the upper teeth, which are not cutting teeth, may help to hold and manipulate the prey. Greenland sharks have many of the modifications for a suction-feeding elasmobranch, including a small mouth laterally enclosed by modified labial cartilages, small teeth (Motta et al. 2002), and a large long pharynx (buccal cavity, Ebert 1994). Wilga and Motta (1998) concluded that spiny dogfish *Squalus acanthias* which is in the same family as the Greenland shark, use suction and ram mechanisms for prey capture and suction for prey transport, and that the species is capable of using a wide variety of food capture strategies on a single food type. Head shaking in the spiny dogfish was used to cut and subdue prey, and to gouge pieces from large prey. Wilga & Motta (1998) suggest that tooth morphology is an important component of the head shaking cutting behaviour. This method of holding the prey with the teeth in both jaws and cutting tissue with the sharp lower teeth is described as the typical "clutching-cutting" method of Squaloids (Shirai & Nakaya 1992). The lack of skeletal damage to seal corpses on Sable Island suggests that the shark in question does not bite down with much pressure. Assuming the prey is captured by suction, the upper teeth may hold the prey in place during a lateral head shaking that would allow the lower teeth to make a sharp cut. In conjunction with prey response and/or head shaking by the shark, the hide tissue with blubber attached is held and pulled by both teeth and suction, and then is torn off the body and the jacket is pulled free of the seal carcass. The helical path of the tear may be explained by the characteristics of collagen fibres present in the skin and blubber of marine mammals. These fibres wind around the body and are oriented in two directions at roughly 45 degrees to the body axis (Brodie 2001). As the tissue is pulled off the seal's body, the tear runs diagonally around the torso and intersects with the tear running in the other direction, thus forming the diagnostic chevron pattern (Fig 3d).

The Greenland shark may selectively feed on the most energy-rich portion of the seal prey. In more than half of the corpses examined, very little to no tissue was missing indicating that, following some attacks, the shark did not feed on the corpse because it was either not a feeding event or that it was a failed feeding attempt. Where tissue was missing, however, it was a section of hide with the blubber layer attached. The energy content of blubber is roughly twice that of muscle tissue (Stirling & McEwan 1975). In young grey seals in good body condition, the blubber comprises 25-40% of total body weight (Addison & Stobo 1993). The fat content of ringed seals in good body condition accounts for 50-85% of the caloric value of the whole corpse (Stirling & Oritsland 1995). It is not unprecedented for predators to selectively consume this layer: in the Canadian Arctic, polar bears *Ursus maritimus* eat mainly the blubber layer of ringed seals (Stirling & Oritsland 1995), and white and blue sharks have been observed to strip the blubber layer off cetacean corpses (Pratt et al. 1982).

Based on current information on distribution, prey preference, foraging behaviour, jaw and tooth morphology, the Greenland shark is the most likely species responsible for the corkscrew wounds. This species is the only large predator known to occur year-round in the Sable Island area and to consume marine mammals as a common part of its diet.

Responses to photographs and diagrams of the corkscrew wounds sent to researchers studying pinnipeds and/or sharks in other regions, including Norway, Iceland, Greenland, Great Britain, California, Alaska and the northeast United States, South Africa and Australia, indicated that such wounds had not been observed elsewhere during this study (1993-2001). However, reports in the British media (e.g. BBC 2010) suggest that similar injuries have been seen recently along the North Sea coastline. Thus it is likely that the Sable Island situation is not unique, and that the Greenland shark similarly preys on seals in other regions where it coexists with pinnipeds. However the scarcity of reports suggests that (a) such predation has not occurred until recently in other regions; (b) it has occurred but the corpses have not been observed or reported because the breeding colonies may be away from land and on ice (Sergeant 1991) making corpses unlikely to wash ashore; and/or (c) similar wounds have been seen but the damage has been attributed to some other agent such as entanglement, ships' propellers, rafting ice, or deliberate mutilation. This type of wound occurred in Atlantic Canada when more than a thousand harp seal pup corpses washed ashore on Prince Edward Island in April 1998 and gave rise to a controversy (Toughill 1998) with claims that a large proportion of the seals had been deliberately mutilated by fishermen or sealers, and counter-claims that the seals had been caught and cut in ice. These wounds, however, were very similar to those on the corpses found on Sable Island and, thus, it is possible that such predation on harp seal pups is not uncommon, but is normally miss-classified.

Our data suggest a prey size limitation for the predator inflicting the corkscrew wounds. Young seals predominated in the corpse totals in all months, peaking during the January-February grey seal pupping season. Most grey seal corpses were pups. In addition to being present in large numbers near the island during much of the year, these young animals, being small and naïve, are likely the most vulnerable. Ainley et al. (1985), Long et al. (1996), and Shaughnessy et al. (2007) also reported that young pinnipeds were more susceptible to attack by sharks. In harbour seals, however, more adults than pups were killed. The adult harbour seal is smaller than the adult grey seal, and thus may represent the upper limit of prey size range for corkscrew predation. Adult male and female harbour seals are 157cm and 149cm in length, respectively, compared with 231cm and 201cm for adult grey seals (McLaren 1993).

The warm and bleeding condition of some beached corpses, and data from TDRs suggest that corkscrew wounds can occur close to shore. In June 1996, two harbour seal pups bearing TDRs (Bowen et al. 1999) were attacked. The data from the TDRs showed that the pups had been killed at midnight, in approximately 2m of water at the north side of the island (W.D. Bowen 1996 pers. comm.). Based on the slope of the island, the pups would have been less than 30m from shore at the time of death (G. Forbes 2006 pers. comm.).

In summary, the patterns and seasonality of shark-inflicted injuries on seals washed ashore on Sable Island indicate that two or more shark species were involved. There is direct evidence that white sharks were responsible for a portion of the attacks on seals during summer and early autumn. Identification of the Greenland shark as the predator responsible for >95% of all shark-killed seals seen year-round at Sable Island, is based on data gleaned from a large number of seal corpses, review of existing knowledge of distribution, behaviour, morphology, and diets of sharks, suggested predatory strategy and distribution and behaviour of seals. The unusual and dramatic corkscrew wound, characteristic of corpses attacked by the Greenland shark, is primarily a tear, not a cut. Young animals comprised the majority of seals killed by both shark species, and it is likely that a proportion were killed close to shore.

Acknowledgements We thank G. Forbes and the staff of the Sable Island Station (Meteorological Service of Canada), and also the Nova Scotia Department of Energy, the Nova Scotia Museum, and ExxonMobil Canada. N.E. Kohler, G. Benz, R. McBride, and W.D. Bowen provided helpful comments on earlier drafts of this manuscript. In addition to personal communications provided by people mentioned above and cited in the references, we greatly appreciate contributions from R. Baird, Cascadia Research Collective, Olympia WA; J. Conway, formerly with Department of Fisheries and Oceans, Halifax NS; T. Curtis, NOAA Fisheries Service Northeast Regional Office, Gloucester MA; K. Goldman, Alaska Department of Fish and Game, Homer AK; J. Pedersen, Newfound Industries, Dartmouth NS; and particularly, J. Casey, Apex Predators Program, National Marine Fisheries Service, Narragansett RI. We also thank the many other persons who have encouraged this research but are far too numerous to mention.

REFERENCES

Addison, R.F., & Stobo, W.T. (1993) Organochlorine residue concentrations and burdens in grey seal (Halichoerus grypus) during the first year of life. *Journal of Zoology, London* 230:443-450.

Ainley, D.G., Henderson, R.P., Huber, H.R., Boekelheide, R.J., Allen, S.G., & McElroy, T.L. (1985) Dynamics of white shark/pinniped interactions in the Gulf of the Farallones. *Memoirs Southern California Academy of Sciences* 9:109-122.

BBC News. (2010) 'Corkscrew' seal deaths probed. http:/www.bbc.co.uk/news/uk-scotland. Accessed August 15, 2010.

Beck, B., & Mansfield, A.W. (1969) Observations on the Greenland shark, *Somniosus microcephalus*, in northern Baffin Island. *Journal of the Fisheries Research Board of Canada* 26:143-145.

Benz, G.W., Hoffmayer, E.R., Driggers III, W.B., Allen, D., Bishop, L.E., & Brown, D.A. (2007) First record of a sleeper shark in the western Gulf of Mexico and comments on taxonomic uncertainty within *Somniosus (Somniosus)*. *Bulletin of Marine Science* 80:343-351.

Bigelow, H.B., & Schroeder, W.C. (1948) Fishes of the western North Atlantic. Pt. I. Lancelets, cyclostomes, and sharks. *Memoirs Sears Foundation for Marine Research* 1:576.

Bowen, W.D., Boness, D.J., & Iverson, S.J. (1999) Diving behaviour of lactating harbour seals and their pups during maternal foraging trips. *Canadian Journal of Zoology* 44:978-988.

Bowen, W.D., Ellis, S.L., Iverson, S.J., & Boness, D.J. (2003a) Maternal and newborn life-history traits during periods of contrasting population trends: implications for explaining the decline of harbour seals (*Phoca vitulina*), on Sable Island. *Journal of Zoology, London* 261:155-163.

Bowen, W.D., McMillan, J., & Mohn, R. (2003b) Sustained population growth of grey seals at Sable Island, Nova Scotia. *ICES Journal of Marine Science* 60:1265-1274.

Brodie, P., & Beck, B. (1983) Predation by sharks on the grey seal (*Halichoerus grypus*) in eastern Canada. *Canadian Journal of Fisheries and Aquatic Sciences* 40:267-271.

Brodie, P.F. (2001) Field studies of the comparative mechanics of skin and blubber from walrus (*Odobenus rosmarus rosmarus*). In: Mazin, J.M., & de Buffrenil, V. (eds), Secondary Adaptation of Tetrapods to Life in Water. Verlag Dr. Freidrich Pfeil, Munchen, Germany, pp. 339-344.

Campana, S., Marks, L., & Joyce, W. (2005) The biology and fishery of shortfin mako sharks (*Isurus oxyrinchus*) in Atlantic Canadian waters. *Fisheries Research* 73:341-352.

Campana, S., Marks, L., Joyce, W., & Kohler, N.E. (2006a) Effects of recreational and commercial fishing on blue sharks (*Prionace glauca*) in Atlantic Canada, with inferences on the North Atlantic population. *Canadian Journal of Fisheries and Aquatic Sciences* 63:670-682.

Campana, S., Brazner, J., & Marks, L. (2006b) Assessment of the recovery potential of shortfin mako sharks in Atlantic Canada. Canadian Science Advisory Secretariat, Research Document 2006/091.

Casey, J.G., & Pratt Jr., H.L. (1985) Distribution of the white shark, *Carcharodon carcharias*, in the Western North Atlantic. *Memoirs Southern California Academy of Sciences* 9:2-14.

Casey, J.G., & Kohler, N.E. (1992) Tagging studies on the shortfin mako shark (*Isurus oxyrinchus*) in the western North Atlantic. *Australian Journal of Marine and Freshwater Research* 43:45-60.

Cliff, G., Dudley, S.F.J., & Davis, B. (1990) Sharks caught in the protective gill nets off Natal, South Africa. 3. The shortfin mako shark *Isurus oxyrinchus* (Rafinesque). *South African Journal of Marine Science* 9:115-126.

Compagno, L.J.V. (1984) Sharks of the world. An annotated and illustrated catalogue of shark species known to date, Part 1. Hexanchiformes to Lamniformes, FAO Species Catalogue FAO, Rome 4:249.

Cortes, E. (1999) Standardized diet compositions and trophic levels of sharks. *ICES Journal of Marine Science* 56:707-717.

Ebert, D.A. (1986) Biological aspects of the Sixgill Shark, *Hexanchus griseus. Copeia* 1:131-135.

Ebert, D.A. (1991) Diet of the sevengill shark *Notorynchus cepedianus* in the temperate coastal waters of Southern Africa. *South African Journal of Marine Science* 11:565-572.

Ebert, D.A. (1994) Diet of the sixgill shark (*Hexanchus griseus*) off Southern Africa. *South African Journal of Marine Science* 14:213-218.

Estrada, J.A., Rice, A.N., Natanson, L.J., & Skomal, G.B. (2006) Use of isotopic analysis of vertebrae in reconstructing ontogenetic feeding ecology in white sharks. *Ecology* (USA) 87:829-834.

Fisk, A.T., Tittlemier, S.A., Prankschke, J.L., & Norstrom, R.J. (2002) Using anthropogenic contaminants and stable isotopes to assess the feeding ecology of Greenland sharks. *Ecology* (USA) 83:2162-2172.

Gilhen, J., & Coad, B.W. (1989) The bluntnose sixgill shark Hexanchus griseus (Bonnaterre, 1788), new to the fish fauna of Atlantic Canada. *Proceedings of the Nova Scotian Institute of Science* 39:75-77.

Hare, M.P., & Mead, J.G. (1987) Handbook for determination of adverse human-marine mammal interactions from necropsies. Marine Mammal Program, National Museum of Natural History, Smithsonian Institution, Washington DC, NWAFC Processed Report 87-06.

Henderson, A.C., Flannery, K., & Dunne, J. (2001) Observations on the biology and ecology of the blue shark in the North-east Atlantic. *Journal of Fish Biology* 58:1347-1358.

Hiruki, L.M., Gilmartin, W.G., Becker, B.L., & Stirling, I.A. (1993) Wounding in Hawaiian monk seals (*Monachus schauinslandi*). *Canadian Journal of Zoology* 71:458-468.

Joyce, W.N., Campana, S.E., Natanson, L.J., Kohler, N.E., Pratt Jr., H.L., & Jensen, C.F. (2002) Analysis of stomach contents of the porbeagle shark (*Lamna nasus* Bonnaterre) in the northwest Atlantic. *ICES Journal of Marine Science* 59:1263-1269.

Kohler, N.E., & Stillwell, C.E. (1981) Food habits of the blue shark, Prionace glauca, in the Western North Atlantic. *ICES Pelagic Fish Committee* H:61:1-7.

Long, D.J., Hanni, K.D., Pyle, P., Roletto, R., Jones, R.E., & Bandar, R. (1996) White shark predation on four pinniped species in central California waters: geographic and temporal patterns inferred from wounded carcasses. In: Klimley, A.P., & Ainley, D.G. (eds), Great white sharks, the biology of *Carcharodon carcharias*. Academic Press, pp 263-274.

Lowe, C.G., Wetherbee, B.M., Crow, G.L., & Tester, A.L. (1996) Ontogenetic dietary shifts and feeding behavior of the tiger shark, *Galeocerdo cuvier*, in Hawaiian waters. *Environmental Biology of Fishes* 47:203-211

Lucas, Z.N. (1992) Monitoring persistent litter in the marine environment on Sable Island, Nova Scotia. *Marine Pollution Bulletin* 24:192-199.

Lucas, Z.N., & Hooker, S.K. (2000) Cetacean strandings on Sable Island, Nova Scotia, 1970-1998. *Canadian Field-Naturalist* 114:45-61.

Lucas, Z.N., & Daoust, Y.-P. (2002) Large increases of harp seals (*Phoca groenlandica*) and hooded seals (*Cystophora cristata*) on Sable Island, Nova Scotia, since 1995. *Polar Biology* 25:562-568.

Lucas, Z.N., & Stobo, W.T. (2000) Shark-inflicted mortality on a population of harbour seals (*Phoca vitulina*) at Sable Island, Nova Scotia. *Journal of Zoology, London* 252:405-414.

McCord, M.E., & Campana, S.E. (2003) A quantitative assessment of the diet of the blue shark (Prionace glauca) off Nova Scotia, Canada. *Journal of Northwest Atlantic Fishery Science* 32:57-63.

McLaren, I.A. (1993) Growth in pinnipeds. *Biological Reviews* 68:1-79.

Moore, J.A., Hartel, K.E., Craddock, J.E., & Galbraith, J.K. (2003) An annotated list of deepwater fishes off the New England region with new area records. *Northeastern Naturalist* 10:159-248.

Motta, P.J., Hueter, R.E., Tricas, T.C., & Summers, A.P. (2002) Kinematic analysis of suction feeding in the nurse shark, *Ginglymostoma cirratum* (Orectolobiformes, Ginglymostomatidae). *Copeia* 1:24-38.

Orlov, A.M. (1999) Capture of especially large sleeper shark *Somniosus pacificus* (Squalidae) with some notes on its ecology in Northwestern Pacific. *Journal of Ichthyology* 39:548-553.

Popov, L.A. (1982) Status of the main ice-living seals inhabiting inland waters and coastal marine areas of the USSR. *FAO Fisheries Series* 5:361-381.

Pratt Jr., H.L., Casey, J.G., & Conklin, R.B. (1982) Observations on large white sharks, *Carcharodon carcharias*, off Long Island, New York. *Fishery Bulletin* 80:153-156.

Ridoux, V., Hall, A.J., Steingrimsson, G., & Olafsson, G. (1998) An inadvertent homing experiment with a young ringed seal, *Phoca hispida*. *Marine Mammal Science* 14:883-888.

Sergeant, D.E. (1991) Harps seals, man and ice. *Canadian Special Publication of Fisheries and Aquatic Sciences* 114:1-153.

Shaughnessy, P.D., Dennis, T.E., & Berris, M. (2007) Predation on Australian sea lions *Neophoca cinerea* by white sharks *Carcharodon carcharias* in South Australia. *Australian Mammalogy* 29:69-76.

Shirai, S., & Nakaya, K. (1992) Functional morphology of feeding apparatus of the cookie-cutter shark, *Isistius brasiliensis* (Elasmobranchii, Dalatiinae). *Zoological Science* 9:811-821.

Skomal, G.B., & Benz, G.W. (2004) Ultrasonic tracking of Greenland sharks, *Somniosus microcephalus*, under Arctic ice. *Marine Biology* 145: 89-498.

Stevens, J.D. (1973) Stomach contents of the blue shark (*Prionace glauca L.*) off south-west England. *Journal of the Marine Biological Association of the United Kingdom* 53:357-361.

Stillwell, C.E., & Kohler, N.E. (1982) Food, feeding habits, and estimates of daily ration of the shortfin mako (*Isurus oxyrinchus*) in the Northwest Atlantic. *Canadian Journal of Fisheries and Aquatic Sciences* 39:407-414.

Stirling, I., & McEwan, E.H. (1975) The caloric value of whole ringed seals (*Phoca hispida*) in relation to polar bear (*Ursus maritimus*) ecology and hunting behavior. *Canadian Journal of Zoology* 8:1021-1027.

Stirling, I., & Oritsland, N.A. (1995) Relationships between estimates of ringed seal (*Phoca hispida*) and polar bear (*Ursus maritimus*) populations in the Canadian Arctic. *Canadian Journal of Fisheries and Aquatic Sciences* 52:2594-2612.

Taggart, S.J., Andrews, A.G., Mondragon, J., & Mathews, E.A. (2005) Co-occurrence of Pacific sleeper sharks *Somniosus pacificus* and harbor seals *Phoca vitulina* in Glacier Bay. *Alaska Fishery Research Bulletin* 11:113-117.

Templeman, W. (1963) Distribution of sharks in the Canadian Atlantic. *Bulletin of the Fisheries Research Board of Canada* 140:1-77.

Toughill, K. (1998) Seal mystery deaths troubling for P.E.I. Experts disagree on why carcasses washed ashore. *The Toronto Star,* April 25, 1998.

Wilga, C.D., & Motta, J.P. (1998) Conservation and variation in the feeding mechanism of the spiny dogfish *Squalus acanthias. Journal of Environmental Biology* 201:1345-1358.

Yano, K., Stevens, J.D., & Compagno, L.J.V. (2007) Distribution, reproduction, and feeding of the Greenland shark, *Somniosus (Somniosus) microcephalus*, with notes on two other sleeper sharks *Somniosus (Somniosus) pacificus* and *Somniosus (Somniosus) antarcticus. Journal of Fish Biology* 70:374-390.

Zwanenburg, K.C.T., Bowen, D., Bundy, A., Drinkwater, K., Frank, K., O'Boyle, R.N., Sameoto, D., & Sinclair, M. (2002) Decadal Changes in the Scotian Shelf Large Marine Ecosystem. In: Sherman, K., & Skjoldal, H.R. (eds), Large Marine Ecosystems of the North Atlantic, Changing States and Sustainability. Elsevier. pp.105-150.

PROC. N.S. INST. SCI. (2010)
Volume 45, Part 2, pp. 89-90

THE NOVA SCOTIAN INSTITUTE OF SCIENCE STUDENT SCIENCE AWARDS 2008-2010

Purpose

To provide an opportunity for students to have their work recognized by a scientific society and to have it considered for publication in a peer-reviewed scientific journal.

Eligibility

The competition is open to any student currently enrolled in a degree program at a recognized educational institution.

Categories and prizes

Undergraduate student

Three broad categories for competition:

Environmental Sciences	e.g. terrestrial ecology, marine biology atmospheric sciences, earth sciences etc.
Life Sciences	e.g. animal and plant cell biology, medical sciences, biochemistry, physiology etc.
Physical Sciences	e.g. physics, chemistry, engineering, mathematics, computer science etc.

Three undergraduate prizes are available in each of these three categories:

1st prize	$200 plus one year's membership to NSIS
2nd prize	$100 plus one year's membership to NSIS
3rd prize	one year's membership to NSIS

Graduate Student

Any discipline
Single prize of $500 plus one year's membership to NSIS

Scientific Writing

For an article written by a student in a non-scientific discipline
Subject must be relevant to science in Nova Scotia
Single prize of $200 plus one year's membership to NSIS

STUDENT SCIENCE WRITING AWARDS – 2008

The 2008 Graduate Student Award Winner was:
Joseph A. Poissant
Department of Biology, Saint Mary's University
for
"Differentiation of two Myotis species (Chiroptera: Vespertilionidae) at Hayes Cave, Nova Scotia, based on echolocation call characteristics"

Note: This paper was revised and co-authored, and is placed amongst the contributed papers of this volume.

STUDENT SCIENCE WRITING AWARDS – 2009

The 2009 Graduate Student Award Winner was:
Gregory R.G. Hutton
School of Information Management, Dalhousie University
for
"Understanding influence of scientific information in the digital age: A study of the grey literature of a United Nations Advisory Group"

The 2009 Undergraduate Student Award Winner was:
Benjamin Langer
University of King's College
for
"The middle ground: Why can't we save nature for nature"

STUDENT SCIENCE WRITING AWARDS – 2010

The 2010 Science Writing Prize was awarded to:
Robyn M. Murphy
School of Physiotherapy, Dalhousie University
for
"Waiting for a cure: Balancing medicine and quality of life for people living with cancer"

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 91-101

2009 Graduate Student Award Winner

UNDERSTANDING INFLUENCE OF SCIENTIFIC INFORMATION IN THE DIGITAL AGE: A STUDY OF THE GREY LITERATURE OF A UNITED NATIONS ADVISORY GROUP

GREGORY R.G. HUTTON
School of Information Management
Dalhousie University
Halifax, Nova Scotia

INTRODUCTION

Today's seriously deteriorating global environmental conditions are pointing increasing attention to the urgent need for more informed use of scientific information in support of effective policy responses. Large bodies of scientific information that should inform policy decisions currently exist and accessibility is increasing in a dissemination milieu that is changing rapidly due to the evolution of the Web. Besides traditional peer-reviewed journals, researchers and information users now have greater opportunities to publish and access scientific information in a wide variety of forms, especially grey literature. Grey literature, a notable form of scientific output, is also being transformed by digital developments.

Briefly defined, grey literature is scientific information published outside of peer-reviewed journals and includes "material in print and electronic formats, such as reports, preprints, internal documents (memoranda, newsletters, market surveys, etc.), theses and dissertations, conference proceedings, technical specifications and standards, trade literature, etc." (Reitz, 2007). As authoritative scientific information, grey literature is often available from the websites of governments, non-governmental organizations, and many other publishing groups. However, greater accessibility to such scientific information due to emerging publication and dissemination methods may or may not lead to improved policy initiatives (de Alwis, 2006; Mitchell, Clark, & Cash, 2006). As a measure of whether marine science grey literature is reaching readers in research and policy communities of practice, this paper reports on a case study that is tracking use of reports of major significance on subjects of marine environmental protection. This study is aided by search tools that identify use as documented in developing digital contexts.

Email: greg.hutton@dal.ca

Unequivocal evidence shows that climate change, the most pressing environmental concern, is affecting natural systems (IPCC, 2007). Stress on the health of marine environments is one of the repercussions of climate change. For example, studies have shown that global sea levels will rise steadily as air temperatures rise and ice sheets and caps melt (Economist, 2009). In addition to problems caused by warming climates, marine systems also suffer from man-made pollution and unsustainable policies and practices, including fertilizer run off causing excessive eutrophication, pollutants such as oils and plastics entering the seas, and overfishing (Economist, 2009). Action to combat the effects of climate change and marine pollution before irrevocable damage has occurred could result from individual and public policy responses informed by authoritative scientific information.

Marine environmental concerns are the domain of many governmental and non-governmental organizations including the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), an international advisory body sponsored by the UN and seven UN-based agencies. Established in 1969 to "provide authoritative, independent, interdisciplinary scientific advice to organizations and member governments to support the protection and sustainable use of the marine environment" (GESAMP, 2008). GESAMP has produced many of its publications as grey literature in a "Reports and Studies" series (Pravdić, 1981; Windom, 1991; MacDonald, Cordes and Wells, 2004). Historically, GESAMP published its reports in print format, and since 2001 most reports have been made available as free, full-text files on the organization's website. Through thorough internal vetting and the requirement that all supporting agencies approve publications, GESAMP's technical reports are arguably more rigorously reviewed than typically occurs in peer-reviewed scientific journals. Thus, these reports, containing important findings, syntheses, and recommendations of global concern, are useful to a wide range of marine environmental policy and management initiatives.

Literature Review

Over the past decade several authors expressed positive outlooks about the influence of grey literature on the general communication of science. At the end of the 1990s Farace wrote that grey literature "in the coming century will be perceived and judged by the contributions it makes in resolving scientific and technical, as well as social problems facing the public and private sectors" (Farace, 1997, p. 73). He cited developments in electronic dissemination technologies and the "breakthrough of network publishing" as factors that will contribute to these developments (Farace, 1997, p. 73). This theme was picked up by Weintraub who pointed out the "relatively long period to effect change in a world that communicates mainly in print" (Weintraub, 2000, p. 55). The author then suggested that the increase in dissemination speeds allowed by internet technologies would "have implications for the formation of science policy and public attitudes in a more profound way than in the past" (Weintraub, 2000, p. 57). While Weintraub was no doubt correct in stating that increased speed of scientific communication has occurred because of the development of internet technologies, it is unknown whether the impact of "quick access" on scientific and public policy communities has occurred. Arguably, the speed of communication allowed by the internet has created a glut of information that has decreased users' abilities to discover relevant, timely information in the manner Weintraub envisioned.

A number of studies have attempted to show that free online access does indeed increase the use of the source. Vaughan and Shaw (2008) mentioned "mounting evidence that publications available on the web are cited more frequently than those that are less readily available" (p. 319). Vaughan and Shaw cite a 2001 study by Lawrence, wherein he argued that "the ability to locate relevant research quickly will dramatically improve communication and scientific progress" (Lawrence, 2001, p. 521). Working with conference articles in computer science, the study showed a considerably higher rate of citation for those articles available online than those that were not (Lawrence, 2001). Recently, Norris, Oppenheim and Rowland demonstrated a distinct citation advantage for open access articles, although they are unsure of why this is the case (Norris, Oppenheim, and Rowland, 2008). Even though the authors were able to establish that there were differences among the ways in which different scientific subjects are cited, they recommended more research to explain the underlying causes of the open-access advantage. While there is evidence that online availability of articles does increase their use and impact, careful consideration of how these documents are being cited needs to be carried out. Thus, we are left with the tenuous assumption that digital access does increase use which will need to be proven through direct analysis of individual incidents of citation.

Methodology

Citation analysis techniques were used to obtain data that track the use of GESAMP's grey literature. Data was collected from three sources: Thomson Reuter's Web of Science, Google Scholar, and Google. Whereas Web of Science citation data have traditionally been used to track uses of scientific publications (Thelwall, 2008), data collected from the three sources enabled building a more complete understanding of GESAMP's influence particularly with regard to publishing and dissemination made possible by developments of the web. Citations found via searches in Google Scholar and Google can track trends in web publishing and Web influence through information sources not indexed by Web of Science. Google Scholar focuses on sources in many disciplines ("peer-reviewed papers, theses, books, abstracts and articles, from academic publishers, professional societies, preprint repositories, universities and other scholarly organizations") (Google Scholar, 2009), and Google provides access to the open Web.

Detailed searches for citations were conducted in Web of Science following a methodology developed by Cordes (2004) to construct a citation dataset for GESAMP reports through to 4 February 2009. Each citing document located in Web of Science was examined to confirm citations to GESAMP reports and then a record of the citing document was entered into a Procite database where each record was coded for ease of analysis (Appendix Table 1).

From the Web of Science dataset the ten most cited and ten least cited were selected as a sample to trace citations to GESAMP's reports in Google Scholar and Google. The title of each report (entire title within quotation marks) was entered into each search engine to conduct phrase searches. When a high number of hits occurred (usually because the title was commonly used in non-GESAMP documents), the GESAMP acronym was added to the search string to narrow the focus to explicitly GESAMP grey literature reports. Only citations to the reports were collected, not citations to the small number of books or journal articles published by GESAMP members based on the reports. Preferences were set in Google Scholar and Google to maximize the efficiency of data collection. Only English language hits were retrieved, and if a hyperlink was not available in a hit to allow investigation of the source, the hit was omitted. To avoid false positive results, each link was opened and the citation to the GESAMP report located. When links were confirmed as citations to GESAMP reports, information was gathered from each citing link, coded, and entered in a Procite database for analysis.

Analysis and Discussion

Aggregate citation data collected from Google Scholar and Google searches for the ten GESAMP reports most cited in Web of Science and the ten least cited reports are presented in Tables 1 and 2. For the ten most cited reports (Table 1), the data show a strong correlation between the total number of citations in Web of Science (576) and Google Scholar (589). The total number of citations retrieved from Google (481) is not markedly different. These aggregate figures suggest that highly ranked reports based on Web of Science cita-

Table 1 Google Scholar and Google Citations: Top Ten Reports

	Number of Citations				
Report Number	**Web of Science**	**G.S. Total**	**G.S. Unique**	**Google Total**	**Google Unique**
38	86	49	11	29	24
32	83	48	10	38	24
39	80	139	55	92	86
50	74	57	27	43	35
61	51	62	40	53	46
06	45	28	16	32	28
57	42	49	18	51	42
28	41	19	9	18	16
71	37	85	52	95	87
58	37	53	26	29	27
Totals	576	589	264	481	416

Table 2 Google Scholar and Google Citations: Bottom Ten Reports

	Number of Citations				
Report Number	**Web of Science**	**G.S. Total**	**G.S. Unique**	**Google Total**	**Google Unique**
23	3	2	1	7	6
16	3	8	7	16	16
29	3	0	0	13	12
11	3	1	1	19	19
07	3	2	2	11	11
05	2	3	1	18	18
75	2	6	4	20	19
20	0	1	1	15	15
36	0	2	2	6	6
76	0	13	13	17	17
Totals	19	39	34	142	139

tions will also rank highly in Google Scholar and Google citations. However, of the 589 citations retrieved from Google Scholar, 264 were different than those found in Web of Science; similarly, of the 481 citations obtained from the Google search, 416 were different than those found in Web of Science. These unique citations in Google Scholar and Google demonstrate that GESAMP's reports are receiving wider attention than is noted by the peer-reviewed journals indexed by Web of Science.

For the ten least cited reports based on Web of Science citations (Table 2), the data show a greater number of citations in Google Scholar (15 more than in Web of Science) and in Google (about seven times more – 139 citations not found in Web of Science). This pattern suggests that GESAMP reports that traditionally obtained the least attention in peer-reviewed journals are now receiving increased notice on the Web.

Further examination of the citations retrieved from Google Scholar and Google reveal additional characteristics of the citing sources. Four reports were chosen for further analysis, based on similar publication dates, subject matter, and the total number of Web of Science citations they received. One older and one newer report were chosen from the ranked list of most cited GESAMP reports in Web of Science and matched with two of the least cited reports. Matching was based on publication dates and similar subject matter to ensure that both of the most cited GESAMP reports were paired with similar least cited reports.

The citations for all four reports obtained from Google Scholar and Google were examined and classified according to the types of documents (see Tables 3 and 4 and Appendix Table 1). The three most numerous categories found in Google (Table 3) are general bibliographies, subject specific bibliographies, and reports. Other less common types include online papers, online books and book chapters, commercial websites selling GESAMP reports, conference proceedings, meeting documents, and proposals. A similar range of citing documents was found in Google Scholar (Table 4), but a dissertation was identified and fewer citations from general bibliographies and subject bibliographies compared to Google were located.

Whereas all citing articles retrieved from Web of Science represent intellectual influence (usually from a scientific perspective due to the focus of the majority of journals indexed by Web of Science), citations retrieved from Google Scholar and Google show a spectrum of influence. Citations in journal articles, technical reports, online books, and meeting documents retrieved from Google Scholar and Google all represent direct use of GESAMP reports. For, example, the sizeable number of technical reports that cite the GESAMP reports (27 and 24 in Google and Google Scholar respectively) highlight intellectual influence. In contrast, the large number of citations in bibliographies (including library catalogues, publishers' websites, GESAMP's own website) indicate awareness of GESAMP's reports but do not confirm that the reports contributed to other scientific studies or to public policy. In the search results from Google, these more perfunctory citations represent 28% of the total (46 out of 165).

Web data must be carefully analyzed before a fair comparison is to be made. Perfunctory bibliographic citations are more prominent for the older reports (Table 5); 85% of the Web citations to report #5 are bibliographic, and 38% of the citations to report #6. By

Table 3 Google Citations to Selected GESAMP Reports

Report Number	Web Science	Google Exports	Biblio	Rep	Subject biblio	Book	Book Chap	Comm	Conf	Jour	Meet	O. P.	Other	Prop	WoS
06	45	32	12	3	1	6	4			1		1			4
71	37	95	15	21	9	9	6	2	4	1	3	7	8	2	8
05	2	18	15	2				1							
75	2	20	4	1	3				3	1	4		3		1

Table 4 Google Scholar Citations to Selected GESAMP Reports

Report Number	Web Science	G.S. Exports	Biblio	Rep	Book Chap	Comm	Conf	Diss	Jour	Meet	O. P.	Other	WoS
06	45	28	1	2	2	3				7			1
12													
71	37	85	1	20	2	12		5	1	7	3	1	
33													
05	2	3		1									
2													
75	2	6		1			1	1		1			2

Table 5 Reports analysed as per perfunctory bibliographic citation.

Report Number	GESAMP Report Title
06	Impact of Oil on the Marine Environment (1976)
71	Protecting the Oceans from Land-based Activities (2001)
05	Principles for Developing Coastal Water Quality Criteria (1977)
75	Estimates of Oil Entering the Marine Environment from Sea-based Activities (2007)

comparison, the newer reports have received fewer bibliographic citations: 16% for report #71 and 20% for report #75. This difference between older and newer reports highlights a broader spectrum of use of more recent publications.

The higher number of bibliographic citations returned in the Google search compared to Google Scholar confirm that the Web sources featured in Google Scholar are focused more towards academic types of information, rather than perfunctory sources, such as publisher's websites. As a result citations resulting from Google Scholar searches are generally indicative of more substantive use of GESAMP's reports.

The widest variety of types of citing documents is illustrated by report #71. Most of the citing documents illustrate substantive use. For example, the report is cited by "Harmful algal research and response: A national environmental science strategy 2005-2015" which is written to support the needs of American scientific and management communities in combating the proliferation of harmful algae blooms (Ramsdell, Anderson, & Glibert, 2005). Similarly, *Japan's position as a maritime nation* shows significant use of report #71 among other GESAMP reports (Hooi, 2007). The online book *Millennium Ecosystem Assessment Volume 3: Policy Responses* refers to GESAMP's scientific findings, namely, the connections between sewage and health problems (Millennium Ecosystem Assessment, 2005). Finally, "The role of policy in the conservation and extended use of underutilized plant species: A cross-national policy analysis" confirms explicit use in a public policy context (Chishakwe, 2008). In each of these examples the citing documents clearly show that report #71 is consulted for scientific and policy-oriented purposes.

CONCLUSION

Tracking the use and influence of scientific information has traditionally relied only on Web of Science as a source of citation data. However, to gain a more comprehensive understanding of the influence of scientific information in the digital age, it is necessary to examine citation evidence drawn from the web. This study illustrates a sizeable number of citations representing GESAMP's influence which are not included in Web of Science data. The significance of citations outside of Web of Science has been shown by the uses of GESAMP's reports in both science and policy contexts. The expansion of the Web in the last five years has increased the visibility and access of scientific information, particularly grey literature which many organizations produce. Evidence from citations drawn from the Web confirms both awareness and substantive uses of GESAMP's reports in conveying important scientific findings as the basis for policy recommendations. Google Scholar and Google are important tools for informing a more complete understanding of the influence of GESAMP's reports. With increasing reliance on open access via the Web, GESAMP, along with other producers of scientific grey literature, are well advised to provide unfettered access on the Web to ensure use. Similarly, to understand the influence of scientific grey literature through citation analysis, the Web must be included as a source of citations rather than relying solely on Web of Science.

Acknowledgements This paper is based on a master's thesis by Hutton, supervised by Dr. B.H. MacDonald of the School of Information Management, Faculty of Management, Dalhousie University, and supported by a research grant from the Social Sciences and Humanities Research Council of Canada to Dr. B.H. MacDonald and Dr. P.G. Wells.

REFERENCES

Chishakwe, N.E. (2008). *The role of policy in the conservation and extended use of underutilized plant species: A cross-national policy analysis.* Rome: Global Facilitation Unit for Underutilized Species (GFU). Retrieved February 15, 2009, from http://www.underutilized-species.org/Documents/PUBLICATIONS/cross_national_policy_analyses.pdf

Cordes, R. (2004). Is grey literature ever used? Using citation analysis to measure the impact of GESAMP, an international marine scientific advisory body. *Canadian Journal of Information and Library Science,* 28:45-65.

de Alwis, G. (2006). Transformation in managers' information seeking behaviour: A review of the literature. *Journal of Information Science,* 32:362-377.

Economist. (2009). Troubled waters. *Economist,* 390(8612):3-4.

Farace, D.J. (1997). Rise of the phoenix: A review of new forms and exploitations of grey literature. *Publishing Research Quarterly,* 13(2):69-76.

GESAMP. (2008). Its mission. Retrieved from http://s244621454.onlinehome.fr/common.php

Google Scholar. (2009). About Google Scholar. Retrieved from http://scholar.google.ca/intl/en/scholar/about.html

Hooi, T.K. (2007). *Japan's role as a responsible maritime nation – Enhancing global presence and commitments (with special reference to resource exploitation and conservation)*. Retrieved February 15, 2009, from http://www.iips.org/07mar/07marTan.pdf

IPPC. (2007). *Climate change 2007: Synthesis Report: Summary for policymakers*. Retrieved February 1, 2009, from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Lawrence, S. (2001). Free online availability substantially increases a paper's impact. *Nature,* 411:521.

MacDonald, B.H., R.E. Cordes and **P.G. Wells.** 2004. Grey literature in the life of GESAMP, an international marine scientific advistory body. *Publishing Research Quarterly* 20(1):25-41.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being Volume 3: Policy responses*. Island Press. Retrieved February 15, 2009, from http://books.google.ca/books?id=dPLzt5uyNAcC

Mitchell, R.B., Clark, W.C., & Cash, D.W. (2006). Information and influence. In R.B. Mitchell, W.C. Clark, D.W. Cash & N. M. Dickson (Eds.), *Global Environmental Assessments. Information and Influence* MIT Press: Cambridge, MA, pp. 307-338.

Norris, M., Oppenheim, C., & Rowland, F. (2008). The citation advantage of open-access articles. *Journal of the American Society for Information Science and Technology,* 59(12):1963-1972.

Pravdić, V. (1981). *GESAMP, the first dozen years*. Geneva: United Nations Environment Programme.

Ramsdell, J.S., Anderson, D.M., & Glibert, P.M. (2005). HARRNESS - Harmful algal research and response: A national environmental science strategy 2005–2015. Washington, DC: Ecological Society of America. Retrieved February 15, 2009, from http://www.whoi.edu/cms/files/HARRNESS_18189_23044.pdf

Reitz, J.M. (2007). *Online Dictionary for Library and Information Science*. Libraries Unlimited. Retrieved from http://lu.com/odlis/odlis_g.cfm#grayliterature

Thelwall, M. (2008). Bibliometrics to webometrics. *Journal of Information Science,* 34(4):605-621.

Vaughan, L. & Shaw, D. (2008). A new look at evidence of scholarly citation in citation indexes and from web sources. *Scientometrics,* 74(2):317-230.

Weintraub, I. (2000). The impact of alternative presses on scientific communication. *The International Journal on Grey Literature,* 1(2):54-59.

Windom, H.L. (1991). *GESAMP: Two decades of accomplishments*. London: International Maritime Organization.

Appendix Table 1

Code	Source of Citations
Biblio	Bibliography (general list of publications, library catalogue)
Rep	Reports (technical reports or reports written for government or interest groups).
Subject Biblio	Subject specific bibliographies
Book	Online books
Book Chap	Specific chapters of online books
Comm	Commercial websites
Conf	Conference-related documents (proceedings, conference papers, workshops)
Diss	Master/PHD theses or dissertations
Jour	Online journal article; journal NOT indexed by Web of Science
Meet	Meeting documents
O.P.	Online paper (without evidence it is from an online journal, conference, etc)
Other	Other sources (blogs, debate notes, news stories, educational websites, and concept notes)
Prop	Proposal documents
WoS	Citing article also appears in a journal indexed by Web of Science

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 102-111

2009 Undergraduate Student Award Winner

THE MIDDLE GROUND: WHY WE CAN'T SAVE NATURE FOR NATURE

BENJAMIN LANGER
Unversity of King's College
Halifax, NS, B3H 3W1

INTRODUCTION - APES AT THE HELM

Human beings as a collective are currently a biogeochemical force unparalleled on the planet. Being ecosystem engineers on a massive scale, we have halved the amount of forest cover that the Earth had 10,000 years ago and replaced it with farmland, settlements and wasteland (Freedman 2008). We and our horde of mutualistic plants and animals have annexed vast stretches of land, more than half the earth (Pimentel and Kounang 1998) and we have fundamentally altered the ecology of lakes and seas. An auspicious outcome of this massive engineering project has been a greatly accelerated extinction rate, approximately 1000 times faster than the natural background rate (Novacek 2007). Many conservationists see the best way of protecting nature from this onslaught to be setting aside vast tracts of pristine wilderness in the form of parks, where humans can sometimes visit but cannot dwell. This sort of conservation, however, is often criticized as overlooking a major component of those landscapes – local people. Sometimes the political turmoil surrounding conservation issues seems to pit the welfare of people against that of the environment.

Are human beings by necessity a detrimental force to ecosystems? Can we rightly speak of a qualitative distinction between 'natural' versus 'managed' ecosystems at all? For instance, some pastures in Europe have had cows grazing on them for so long that they seem to have reached an anthropogenic stable state, with some biologists calling for their preservation as a conservation strategy (Fink *et al.* 2002). The same sort of situation could be true of much of the American plains before the arrival of Europeans, as Native Americans used controlled burning to control forest cover and therefore increase their hunting grounds (Howe 1994). Some human activities, such as replacing old growth tropical forest with oil palm monoculture, assuredly reduce biodiversity. Others though, like the cloud gardens and complex agroforests found in the tropics, may help preserve it.

The first part of this essay will sketch some of the history of ecology in order to understand how changing ecological ideas can change our understanding of our own role in nature. The idea that humans necessarily upset a pre-existing 'balance' has its roots in early ecological thinking, but more recent study has largely abandoned this notion. The second part will consider how to improve the 'middle ground', the place between the purely cultural and the purely natural in which humans actually dwell and make a living. This is where the real battle against ecological destruction will take place.

Part I: Harmony and Discord: Where Have We Come From?

Ecology as we know it today was set into motion by the 19th century biological geographer, Alexander von Humboldt. Humboldt was the most notorious world traveler of his day, intent not only on describing and classifying organisms, but explaining why they occurred where they did. For him, mountains provided much of the world condensed into one place, for as he ascended hundreds of metres, the biotic communities changed just as they would if he had traveled hundreds of miles toward the poles. Thus, in his explanations for the distribution of organisms, climate took the preeminent explanatory role. Presciently, he wrote that these observations "furnished the rough materials for a science, to which no name had as yet been given" (Humboldt 1866). Just twenty years later, the German evolutionist Ernst Haeckel would coin the word *oecology* for the "the comprehensive science of the relationship of the organism to the environment"(Haeckel, in Worster 1994).

In 1895, the Danish botanist and geographer Eugenius Warming was the first to truly lay out the scientific program of ecology, dealing in his book *Plantesamfund* with the plant communities of every major biome (Worster 1994). Warming showed how the plant communities everywhere in the world, although consisting of entirely different species, adapted to the various environmental challenges they faced in very similar ways. Although Warming was an evolutionist, he and many of the early founders of ecology were believers in neo-Lamarckism, or the inheritance of acquired characteristics. Frederic Clements, a newly minted botanist at the University of Nebraska just at the time Warming's work was filtering into America, was also strongly influenced by neo-Lamarckism. Clements was very taken with the holistic theories of British neo-Lamarckian philosopher Herbert Spencer, especially his ideas of the super-organism, which he applied to plant communities (Tobey 1981). He thought of assemblages of plant species as organic entities in and of themselves, with corresponding cycles of birth, growth, and death. Following Humboldt's emphasis on climate, for every particular set of climatic conditions, Clements thought that a very particular kind of species assembly would occur, developing through many successional stages. Each stage paved the way for the next one until the fully mature form of the ecological super-organism was reached, termed its climax (Clements 1935). Clements' 1916 book *Plant Succession*, in which he laid out this theory of the 'monoclimax,' became the standard of ecology for the next thirty years.

For Clements, though unpredictable factors and chance events might deflect a plant community from its trajectory, the eventual destination was a single unalterable one (Clements 1935). In this picture humanity was not able to truly upset the nature of things, and any designs of our own stood firmly outside of the true natural order. While the monoclimax held sway over a whole generation of ecologists, there were plenty of dissenters. British ecologist Arthur Tansley, originally one of Clements' most ardent supporters, decided in 1935 that the super-organism idea was untenable. In his paper "The use and abuse of vegetational concepts and terms" he replaced the super-organism with the term ecosystem (Tansley 1935). Tansley advocated for a less strict interpretation of the climax, and rejected the notion that humans could not play a constructive role in the formation of stable climax communities. It is interesting to note that while Clements did his work on the wild American prairie, Tansley did his in England, most of which had been under human influence for thousands of years.

Another critic, Henry Gleason, argued in 1926 for what he called an individualistic view of communities, the pure antithesis of Clements' super-organism. Gleason saw succession as nothing more than the sum of individual organisms striving to do what organisms do: grow and reproduce (Gleason 1926). It was the outcome of all the little struggles between individuals; if there was regularity it was only because the players and their behaviors were often the same and they were adapted to the same climate. In this view humans are just individuals playing out their role in nature, with human-influenced climaxes not essentially different from natural ones in any qualitative way. This does not exonerate people for ecologically destructive behavior but blurs the formerly clear cut line between natural and human-influenced communities. Largely ignored and overshadowed by Clements until the 1950's, Gleason's views have since grown in popularity. The story of ecology since 1900 can in some ways be seen as an oscillation between the ideas of Clements and those of Gleason.

The true test of Clements' ideas came during the great drought of the 1930's. This prolonged dry period caused a phenomenon known as the Dust Bowl, in which vast tracks of the American and

Canadian prairie lost plant cover and blew away. This ecological catastrophe was intensified by the fact that huge tracts of the prairie had, in the previous generation, been ploughed up and planted with wheat, leaving the soil far more vulnerable to the desiccating wind (Worster 1994). During this period ecology was thrust into the public sphere, and for the first time ecologists were called upon to use their field of knowledge to assess the situation and provide practical solutions (Tobey 1981). Much of this work was based on the ecological ideas of Clements, and Clements himself was quite involved in the matter. Through comprehensive studies of prairie vegetation before and after the Dust Bowl, many people came to the conclusion that some grassland communities had permanently changed as a result of the drought, contradicting predictions of Clements' monoclimax theory. Also, while before the Dust Bowl the prairie school's view was that human action could only deflect the natural climax succession, afterwards some were calling for human action as the only way to *preserve* this native climax (Tobey 1981).

The sixty years since the Dust Bowl has seen a great proliferation of ecologies: evolutionary, physiological, systems, population, community, and ecosystem ecology are just some of the various routes a professional ecologist might take today. Many of the questions still, however, centre around what holds biological communities and ecosystems together and what makes them work. Often, the questions arise out of and have implications for the way in which humans interact with the living systems around us. One example of a major area of research in this vein concerns the relationship between biodiversity and ecosystem stability. If we are disturbing biological communities and decreasing biodiversity, how will this affect their functions and processes? The biodiversity-stability question has its roots in a simple question, most lucidly put forward by G.E. Hutchinson in his influential 1959 address titled "Homage to Santa Rosalia, or why are there so many kinds of animals?" The answer that he put forward has had a large impact on ecology, and reverberates through the environmental movement: "the reason why there are so many species of animals is at least partly because a complex trophic organization [food web] of a community is more stable than a simple one" (Hutchinson 1959).

This idea had, and still has, an intuitive appeal to many. In 1973, however, Robert May overturned Hutchinson's hypothesis based on mathematical analyses of food webs. May showed that instead of stability increasing with increasing diversity, it actually *decreased* (Worster 1994). Using different mathematical models, many other mathematical biologists began to corroborate this contrary position, while some field studies instead supported Hutchinson's original view

(Tilman 2006). This debate continues in ecological research, with comprehensive empirical studies few and far between. According to David Tilman in a 2006 paper in *Nature*, while our understanding has greatly improved, contrary views continue to be published and even the best studies yield inconclusive results. The relationship between diversity and stability will most likely not follow a direct correlation or an asymptotic one, but instead an idiosyncratic one, with the impact of species loss or gain having a unique effect on stability depending on that species particular characteristics. Species are not elements or molecules, and extrapolating from the particular to the general in ecology is always fraught with difficulty.

A related notion that has been largely abandoned within the last generation of ecology has been that of stable equilibrium states around which ecosystems fluctuate, akin to the popular notion of the 'balance of nature' (Stevens, 1990). In contemporary ecology, Gleason's view has largely won out over Clements'. Sometimes the gazelle *will* be driven to extirpation or extinction by the lions, says more recent thinking. Sometimes drought *will* alter the basic conditions of an ecosystem. Paleoecology has brought to our attention that climatic changes are a regular phenomenon of the planet, constantly causing biological communities to shift and reinvent themselves (Novacek 2007). The massive Boreal forest that rings the Earth did not exist until the end of the last ice age some 15,000 years ago, when the glaciers that stood in their place began to retreat (Lindsey 2002). Species outcompete one another, the loser being driven to extinction. Invasive species are not a new phenomenon; the recent concern is about how rapidly human activity is shuffling species around the planet. Rather than just noise around a stable point, disturbances are now seen as a major force in structuring ecosystems, such as in the flood/fire cycles of the Everglades (Walker and Salt 2006). The concept that upon awakening our procreative and technological potential, humans have upset some ancient mystical balance is not borne out by modern ecology. While the storybook version of ecology is still reiterated by environmentalists and the media, we can now say fairly certainly that the "balance of nature" view is untenable. With this in mind, we are faced with the question 'well then, what needs saving?' As Lynne Margulis puts it in her book *The Symbiotic Planet,* "We cannot put an end to nature; we can only pose a threat to ourselves" (Margulis 1998). Rachel Carson said very much the same thing 40 years earlier in her writings about the sea.

Part II: Battle for the Middle Ground – Where Are We Going?

In a 2005 article in *Orion* magazine titled "Conservation Refugees: when protecting nature means kicking people out," Marc Dowie wrote that while it is well recognized that native peoples have been pushed off their land as a result of resource exploitation and commerce, “few people realize that the same thing has happened for a much nobler cause: land and wildlife conservation. Today the list of culture-wrecking institutions put forth by tribal leaders on almost every continent includes not only Shell, Texaco, Freeport and Bechtel, but also more surprising groups such as Conservation International (CI), The Nature Conservancy (TNC), the World Wildlife Fund (WWF), and the Wildlife Conservation Society (WCS)” (Dowie 2005). In the world today, there exist more than 15 million so called ‘conservation refugees,’ people whose very existence clashed with the classical idea of wilderness, laid out in the US Wilderness Act of 1964: “an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain” (in Dowie 2005). Conservation refugees throw the major philosophical assumption of the Wilderness Act in stark relief. It says: “For nature to be truly natural, and therefore pristine, it needs to be free from the meddling activities of humans”. True nature and human habitation are mutually exclusive. As the brief historical sketch has shown, however, this sort of assumption is not drawn from the study of nature, but is an idea imposed onto it. It might be useful or detrimental, depending on the situation, but it should not be accepted as absolute truth.

The major problem with this dividing line is that it separates the world around us into two neat categories: pristine nature, regarded as being in a fragile balance that our actions could disrupt, and everything else, regarded as the part of the world firmly under human control. A large amount of focus is being put on the preservation of the pristine, but it is not how much land we can save in its ‘virgin’ state that will determine our survival. It is how we treat the land under our control. A caveat, however, is needed at this point. I understand that the argument I am making is polemical, and will rub some people the wrong way. Parks and wilderness areas are undoubtedly a very important part of any global environmental strategy, but their implementation must deal with human and economic realities. A notable trend from around the world raises the question of whether the exported American idea of wilderness will really bring about long term progress. As Douglas Adams has pointed out in his wonderfully incisive way in *Last Chance to See*, the economic model usually works like this: natural areas are exploited precisely to the point where it becomes more economically viable to preserve them for tourism and parks than to exploit them further. As economic circumstances change, however, so may attitudes towards the natural areas (Adams 1992). Another recent strategy, paying the poor of the world not to exploit natural areas, is even less sustainable; in the long run people don't need money for nothing, they need lasting livelihoods.

In the case of the 15 million conservation refugees, Downey notes that displaced people are usually slowly and awkwardly brought into the monetary economy where they end up on the bottom rungs of the socio-economic ladder. Whereas before they may have lived off the land in a relatively harmless way, they are now members of that ever-growing class, the landless poor, who occupy the fringes of the largest cities in the world (Dowie 2005). These people contribute to the demand for cheap industrial food and products that further drives the degradation of the middle ground. This degradation in turn creates market pressure to exploit new resources. Consider this: the amount of arable land in crop production today is about equal to the amount of land that has been abandoned since the advent of agriculture (Pimentel and Kounang 1998). Historically this abandonment follows mistreatment, which arises from the same sort of economic pressure felt by farmers around the world today: get big or get out (Montgomery 2007). In the past, when there were but few people, there were always greener pastures or new continents to colonize when good land ran short. If this sort of degradation continues today, however, governments will not be able to justify keeping pristine parks full of valuable soil and plant resources while their people starve. And the billions of rural poor, needing to squeeze another little bit out of the land to survive, will not care about the intrinsic values of pristine nature. This is why our survival must start in the middle ground, for without the middle ground the 'pristine' parks are lost as well.

How then should we approach the management of the middle ground? Ecology has not borne out the idea of the sacred balance and the human/nature divide, but that doesn't mean that we can't use ecology to evaluate our actions and long-term plans. An emerging concept, one that underpinned the UN's 2005 Millennium Ecosystem Assessment (MEA), is ecosystem services. Ecosystem services are defined in the MEA report as "the benefits people obtain from ecosystems" (MEA 2005). Ecosystems here are defined broadly enough to include everything from the conservation area hours away to the little garden on the roof of an apartment or office building. A major aspect of the ecosystem service idea, and one that has made many people uncomfortable, is that in its framework a price can be put on things like the flood prevention and microclimate regulating services of a forest, services that wouldn't exist if the forest was cut down for timber. Global markets now exist for services like carbon sequestration, and are generally the rationale for paying people to leave forests intact. The question of just how much global markets can be trusted to maintain the conservation incentive, especially in tumultuous economic times, is an open one.

Using the ecosystem services model as a guide, there exist other routes to managing the middle ground so that degradation is avoided and the ecosystems improved. The essential goal is to fit the land use strategy to the land itself and to diversify and optimize the ecosystem services provided (Bennett and Balvenera 2007). As an example, where there are steep slopes and thin rocky soil, annual cereal crop agriculture will not do. While it may provide one ecosystem service, that of food provision, it seriously lacks those of erosion control, soil carbon sequestration and others. A much better land use strategy would be planting trees on such landscapes if the native forest is already cut down, or leaving the native forest intact if it is not. This strategy would provide those ecosystem services lacking in the former strategy. If, however, one still wanted to use the land for food production, many options are available, such as silvopasture (trees and pasture together), tree crops, cultivation of non-timber forest products below a natural forest canopy, and other forms of so called agroforestry. In time, trees could also be cut for timber in a rotation or tapped for resin and syrup. In Canada, 50-57 million hectares of marginal and degraded land could be put into these sorts of systems, improving ecosystem services a great deal (Thevathasan and Gordon 2004). It must be emphasized that agroforestry is not for all land, and this is just the point. In Kansas, the goal would be growing food like a prairie, while in Colorado it would be growing food like an alpine forest.

Since systems like this provide a wide variety of services all in one place, pressure is eased on places set aside for protection, as the need doesn't exist for their exploitation. They are economically sustainable due to the diversified income they provide and their lower need for inputs such as fertilizer and pesticides. This sort of model urgently needs to be adopted not only in places like Argentina, which now devotes more than half of its agricultural land to soybean production for export (GRAIN 2009), but in places like Nova Scotia, where vast potential exists on our marginal forests and abandoned farmlands. If managed properly and intensively, there is no reason why we could not use this strategy to improve both our ecosystem services and our agricultural, forestry, and tourism sectors at the same time. This would not only help our own economy, but in taking international market pressure off the soybean fields of Argentina and the oil palm plantations of southeast Asia, it would help those countries develop similar methods fitted to their own particular situation. Even such seemingly small actions as planting more trees in our urban areas and diversifying the services provided by the green spaces in our communities can, when scaled up to a global level, turn the tide in the battle for the middle ground.

Bringing the fruits of this way of thinking to bear will require a sustained act of political and economic will on the part of governments and people. An important step in making this happen is the recognition that while capital N nature is important, the battle for nature is really in everyone's backyard. The title of the MEA synthesis report is "Ecosystems and Human Well Being," not 'the well-being of ecosystems', and this message should be taken to heart. Rather than wishing we could disappear so that nature can live, we need to recognize our current position on Earth: human actions collectively have greater negative influence on the functioning of the biosphere than any other biotic factor. Like it or not, we are increasingly at the helm of Gaia, and we had better learn to steer Mother Earth. To draw on a popular comic for an appropriate adage for the situation: "With great power comes great responsibility." Saving nature for nature is tantamount to escapism in the face of this challenge. As Margulis states, in the end nature will take care of itself. Let us do the same.

REFERENCES

Adams, D. (1992) *Last Chance to See.* Ballantine Books.

Bennett, E and Balvanera, P. (2007) The future of production systems in a globalized world. *Frontiers of Ecology and the Environment.* 5(4):191-198.

Clements, F. E.(1991) Nature and Structure of the Climax. In: Real, Leslie and Brown, James H. (ed), *Foundations of Ecology: classic papers with commentary.* University of Chicago Press, Chicago. pp.59-97

Dowie, M. (2005) Conservation Refugees: when protecting nature means kicking people out. *Orion Magazine:* November/December.

Fink, P., Riecken U. and **Schroder E.** (2002) Pasture Landscapes and Nature Conservation- New strategies for the preservation of open landscapes in Europe. In: Redecker, Bernd (ed) *Pasture Landscapes and Nature Conservation.* Universitat Luneberg, pp. 1-13.

Freedman, B. (2008) Lecture notes for BIOL3060: Environmental Ecology.

Gleason, H. (1991) The individualistic concept of the plant association. In: Real, Leslie and Brown, James H. (ed), *Foundations of Ecology: classic papers with commentary.* University of Chicago Press, Chicago. pp. 98-117

GRAIN. (January 2009) Twelve years of GM soya in Argentina. *Seedling: Biodiversity, Rights, and Livelihood.* <www.grain.org/seedling/?id=578>

Howe, H. (1994) Managing Species Diversity in Tallgrass Prairie: Assumptions and Implications. *Journal of Conservation Biology* 8(3): 691-704.

Humboldt, A. (1866) Cosmos. Vol I trans E.O. Otte. Harper Brothers, Publishers, New York.

Hutchinson, G.E. (1991) Homage to Santa Rosalia, or why are there so many kinds of animals? In: Real, Leslie and Brown, James H. (ed), *Foundations of Ecology: classic papers with commentary.* University of Chicago Press, Chicago. pp. 342-356.

Lindsey, R. (August 20, 2002) The migrating Boreal forest. *NASA Earth Observatory.* <earthobservatory.nasa.gov/Features/BorealMigration>.

Margulis, L. (1998) *Symbiotic Planet: a new look at evolution. Basic Books,* New York.

Millennium Ecosystem Assessment. (2005) *Ecosystems and Human Well-being: Synthesis: a report.*

Island Press, Washington, DC.

Montgomery, D. (2007) *Dirt, the erosion of civilizations.* University of California Press, Berkeley.

Novacek M. (2007) *Terra: our 100-million-year-old ecosystem – and the threats that not put it at risk.* Farrar, Straus and Giroux, New York.

Pimentel, D. and Kounang, N. (1998) Ecology of Soil Erosion in Ecosystems. *Ecosystems* 1(5):416-426.

Stevens, W. (July 31, 1990) New Eye on Nature: The Real Constant Is Eternal Turmoil. *New York Times.* July 31, 1990: C1.

Tansley, A. G. (1991) The use and abuse of vegetational concepts and terms. (1935) In: Real, Leslie and Brown, James H. (ed), *Foundations of Ecology: classic papers with commentary.* University of Chicago Press, Chicago. pp. 318-341.

Thevathasan, N and Gordon, A. (2004) Ecology of tree intercropping systems in the North temperate region:Experiences from southern Ontario, Canada. *Agroforestry Systems.* 61-62 (1-3):257-268.

Tilman, D. (2006) Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature.* 441(7093):620-632.

Tobey, Ronald. (1981) *Saving the Prairies: The Life Cycle of the Founding School of American Plant Ecology,* 1895-1955. University of California Press, Berkeley.

Walker, B and **Salt, D.** (2006) Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Island Press, Washington.

Worster, D. (1994) *Nature's Economy – A History of Ecological Ideas* 2nd ed. Cambridge University Press, New York.

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 112-124

2010 Science Writing Prize

WAITING FOR A CURE: BALANCING MEDICINE AND QUALITY OF LIFE FOR PEOPLE LIVING WITH CANCER

ROBYN M. MURPHY
School of Physiotherapy
Dalhousie University
Halifax, Nova Scotia, B3H 3J5

INTRODUCTION

Cancer is a very complex disease, which our society has been unable to eradicate. The fact that we have been unsuccessful in finding a cure for cancer is not surprising given that this disease has been evolving and changing since it was first described in Egypt in 1600 B.C. (American Cancer Society 2009). Cancer is characterized by abnormal cell division resulting in invasion of tissues and tumour growth (National Cancer Institute 2010). Today over 100 types of this ancient disease exist (National Cancer Institute 2010). In Nova Scotia 6000 new cases were expected in 2009 (Canadian Cancer Society's Steering Committee 2009). It is estimated that 171,000 new cases of cancer were identified across Canada last year (Canadian Cancer Society's Steering Committee 2009). This translates to approximately 470 Canadians being told each day that they have cancer (Canadian Cancer Society's Steering Committee 2009). Imagine how that moment changes a life forever.

Once the diagnosis of cancer is confirmed, patients usually follow various daily, weekly, or monthly regimens of radiation therapy, chemotherapy, or other drug therapies. Whether these measures are for curative or palliative purposes, the side effects can be both physically and mentally debilitating. Once treatment is completed, and even during treatment, many patients find themselves looking for direction on how to improve their overall health. There is a large amount of research supporting exercise as a means of addressing both the effects of cancers and adverse effects of cancer treatment (Courneya & Friedenreich 2007, Galvão and Newton 2005, Hayes *et al.* 2009). From my perspective as a researcher and physiotherapist, we are not doing enough to ensure that cancer survivors are aware of the benefits of exercise and more importantly are participating in a regular exercise program. Although we may not have a cure for this disease, all cancer survivors should be well informed of the fact that exercise could improve their quality of life (QOL) while they are living with cancer. In addition to this valuable knowledge is the early research showing that exercise may prevent cancer recurrence in some cases (Courneya *et al.* 2004). This paper discusses how exercise may prove to be the key to balancing medical or radiation cancer treatments and QOL. It also summarizes the various mechanisms behind these ideas and presents the many positive reasons why people with cancer should engage in exercise programs.

WHAT IS QUALITY OF LIFE?

Quality of life is defined differently across the health care literature (Hacker 2009). It is clear that QOL is a multidimensional concept that includes all aspects of a person's life (Hacker 2009). The University of Toronto QOL Research Unit explains QOL with the use of a conceptual framework (*Quality of life concepts* 2009). They state that QOL is "The degree to which a person enjoys the important possibilities of his or her life" (*Quality of life concepts* 2009). There are three domains with three sub-domains, each including being (physical, psychological, spiritual), belonging (physical, social, community), and becoming (practical, leisure, growth) (*Quality of life concepts* 2009). It is easy to understand how cancer could cause a sharp decline in QOL for some people. Many factors play into this change in QOL, but Visser and Smets (1998) concluded that QOL for cancer survivors is mainly predicted by fatigue and depression. Dagnelie *et al.* (2007) highlight the impact of fatigue on QOL for patients with breast or lung cancer undergoing radiotherapy. They found a high correlation between fatigue and overall QOL ($r = -0.76$; $P < 0.001$), concluding that patient-perceived fatigue is the primary factor in QOL (Dagnelie *et al.* 2007). A large group of Chinese women with breast cancer being treated with radiotherapy or chemotherapy reported a "cluster" of symptoms including mainly fatigue and pain, but also depression and anxiety (So *et al.* 2009). The authors found significant correlations among these symptoms which all resulted in negative changes in QOL (So *et al.* 2009).

The best way to measure QOL is to ask for the individual's perspective as they are the most appropriate to judge their own QOL (Hacker 2009). There are several valid and reliable outcome measures available for examining QOL in patients with cancer. Unfortunately these tools are not used regularly to screen patients with cancer for changes in QOL. Complete treatment of any cancer patient should include assessment of the various domains of their QOL. This information can guide the decision-making process for adjunct therapies, possibly identifying the need for regular physical activity (PA) when appropriate.

THE BENEFITS OF EXERCISE FOR CANCER SURVIVORS

The evidence continues to grow showing that exercise is beneficial in preventing cancer and improving the health status of cancer survivors (Courneya and Friedenreich 2007, De Backer *et al.* 2009, Galvão and Newton 2005, Hayes *et al.* 2009). Although the symptoms of cancer and the side effects of treatment vary greatly among patients, exercise is considered to be an advantageous adjunct therapy during and after medical treatment or radiation (Mustian *et al.* 2009).

Fatigue is one common complaint from cancer survivors which is often debilitating enough to cause problems in physical performance while inducing feelings of depression and anxiety and negatively impacting QOL (Dimeo 2001). Recent reviews on the effects of exercise in breast cancer survivors suggest that exercise enhances physical functioning, may mitigate fatigue, and improves QOL (Bicego *et al.* 2009, Markes *et al.* 2006, McNeely *et al.* 2006). Management of fatigue for breast cancer survivors may be as simple as 90 minutes of walking on three or more days per week (Mock *et al.* 2001). Last year, Chen *et al.* (2009) released results from a study which included 1,829 breast cancer survivors. At 36 months post-diagnosis they found that non-regular exercisers had lower QOL scores compared to those who exercised regularly at high intensities (Chen *et al.* 2009). The women in this study reported noticeable positive changes in physical, psychological and social well-being (Chen *et al.* 2009). Similarly, another group of sedentary breast cancer survivors, notably older women, reported worse moods and lower self esteem when compared to regular exercisers (Pinto and Trunzo 2004).

In 2003, Courneya *et al.* concluded that postmenopausal breast cancer survivors benefited from a 15 week exercise training protocol with dramatic improvements observed in QOL ($P = 0.001$), fatigue ($P = 0.006$) and aerobic capacity ($P < 0.001$) (Courneya *et al.* 2003). Another study had an even shorter training time of 12 weeks, combining both aerobic and strengthening exercises. These participants also reported substantial boosts in health-related outcomes and breast cancer specific QOL (Milne *et al.* 2008). A unique 2007 study distributed print materials about physical activity along with step pedometers (Vallance *et al.* 2007). They found that breast cancer survivors increased their physical activity by almost 90 minutes per week (Vallance *et al.*, 2007). This increase in activity resulted in lower fatigue levels ($P = 0.052$) and higher QOL scores ($P = 0.003$) (Vallance *et al.* 2007).

Yoga is becoming more popular with the general public and with breast cancer survivors. Studies have shown that yoga is effective in enhancing emotional outcomes and reducing fatigue in patients with cancer (Danhauer *et al.* 2009, Vadiraja *et al.* 2009). It is thought that the combination of exercise, improved breathing awareness, and the associated sense of relaxation are contributing factors in explaining how yoga improves QOL (DiStasio 2008). One encouraging study showed that this complementary therapy could significantly reduce chemotherapy-induced nausea and emesis ($P \leq 0.05$) as well as improve feelings of depression, anxiety and distress (Raghavendra *et al.* 2007). Twelve weeks of yoga proved to be beneficial when compared to the waitlist control group and resulted in an improvement in overall QOL ($P < 0.008$) and emotional well-being ($P < 0.015$) among a multi-ethnic group of breast cancer survivors (Moadel *et al.* 2007).

Echoing the results from breast cancer research, studies involving prostate cancer survivors have concluded that exercise positively impacts various areas of life including physical function, muscular fitness, HRQOL and fatigue (Thorsen *et al.* 2008). A pioneer study examined the effects of exercise in men with prostate cancer specifically undergoing androgen deprivation therapy (ADT) (Segal *et al.* 2003). The men who completed 12 weeks of resistance training reported higher QOL scores ($P = 0.001$) and less fatigue when performing activities of daily living ($P = 0.001$) compared to the men in the usual care group who did not partake in any exercise programs (Segal *et al.* 2003). Four years later Galvão *et al.* (2007) released a review of the three existing studies on the topic of ADT and exercise which all showed positive results in subjective and objective tests. It prompted the researchers to recommend that men on ADT should participate in regular strengthening and aerobic exercise regimens to reduce the many side effects associated with this treatment (Galvão *et al.* 2007). Another study involving men receiving radiation therapy with or without ADT found that resistance training and perhaps aerobic training reduce fatigue (Segal *et al.* 2009). Resistance training may also improve overall QOL ($P = 0.015$) and other health outcomes such as percent body fat ($P = 0.049$) and triglyceride levels ($P = 0.036$) (Segal *et al.* 2009). The most recent study released involving PCa survivors had 57 patients who were undergoing ADT participating in a combined aerobic and resistance exercise program for 12 weeks. Of interest here is the reduction in feelings of fatigue ($P = 0.021$) and some domains of QOL including general health ($P = 0.022$) and vitality ($P = 0.019$) (Galvão *et al.* 2010).

Exercise studies involving colorectal and bladder cancer survivors are also hopeful. A questionnaire completed by colorectal cancer survivors revealed that those who met public health exercise guidelines reported increased QOL and reduced fatigue compared to those who do not meet these guidelines (Peddle *et al.* 2008). Meeting the minimum standard was defined as 60 minutes of strenuous intensity exercise or 150 minutes of moderate to strenuous intensity exercise per week (Peddle *et al.* 2008). A 2003 randomized trial compared QOL in those participants who decreased PA versus those who increased PA compared to baseline reports (Courneya *et al.* 2003). A significant difference in QOL was observed on the Functional Assessment of Cancer Therapy-colorectal scale (a cancer-specific QOL questionnaire) between these two groups in favour of those who increased PA ($P = 0.038$) (Courneya *et al.* 2003). Additionally, a population-based study of bladder cancer survivors concluded there that there is a linear association between meeting recommended PA guidelines and QOL (Karvinen *et al.* 2007). When compared to sedentary survivors, those who exercised showed positive changes in cancer-specific QOL ($P = 0.001$), bladder cancer specific QOL ($P < 0.001$), and various fatigue scales ($P < 0.05$) (Karvinen *et al.* 2007).

Some researchers suggest that an overall lifestyle modification such as a low fat diet, high fruit and vegetable consumption and PA are all needed to observe meaningful changes in QOL (Blanchard *et al.* 2004, Demark-Wahnefried *et al.* 2004, Doyle *et al.* 2006). Blanchard *et al.* found that patients with cancer who met more than one lifestyle modification recommendations (i.e. smoking cessation, physical activity) had significant increases in health related QOL (Blanchard *et al.* 2004). However, it is demonstrated here that there are several beneficial physical and mental effects, including domains of QOL, observed with various types of exercise such as aerobic, resistance, yoga, and combined programs. Interestingly, a systematic review published earlier this year concluded that high levels of physical activity can even reduce a cancer survivor's risk for mortality, or put another way, their quantity of life (Barbaric *et al.* 2010).

ANOTHER WORD ON MENTAL HEALTH

The risk and prevalence of depression increase with physical inactivity (aan het Rot *et al.* 2009). Therefore, physical activity can be especially vital in managing the overall care of patients with cancer who are at risk for or those with depression. However, depression can also affect someone's motivation to exercise (aan het Rot *et al.* 2009). Depression may actually lead to a sedentary lifestyle (Roshanaei-Moghaddam *et al.* 2009). Regular screening procedures for both depression and activity levels are pivotal in identifying those individuals who may need more direction and supervision with exercise programs. Although there is evidence supporting exercise in the reduction of depressive and anxiety symptoms, there is a lack of knowledge translation in this area (Strohle 2009). This means that the information is current and available, but we are not telling our patients about it. A crucial action needed in some cases is interpretation of the data, proving that exercise decreases symptoms of depression (Mead *et al.* 2009). Although to some this might seem to be common knowledge, many people would not be aware of this relationship. Finally, the development of exercise programs for people with depression or anxiety may be warranted (Strohle 2009). Specific tactics such as an exercise journal, group-based activity sessions, or weekly check-ups may be needed to improve motivation and adherence.

WHY EXERCISE WORKS

Exercise improves both mental and physical health thereby improving one's overall QOL. This is true for everyone, not only cancer survivors. The beneficial effects of exercise on mood can be both psychological and physiological. Psychological changes are seen because of the distraction, self-efficacy and social interaction that can accompany regular physical activity routines (Peluso *et al.* 2005). The two most accepted physiological reasons for improvements in mood and QOL include changes in the neurotransmitters called monamines and endogenous opioids called endorphins (Peluso *et al.* 2005). First, physical activity increases monoamine (i.e. serotonin, norepinephrine) transmission, which is similar to the response observed in patients taking anti-depressive medications (aan het Rot *et al.* 2009, Peluso & Guerra de Andrade 2005). These neurotransmitters are more available for synaptic uptake, which is believed to improve one's mood (aan het Rot *et al.* 2009). Second, endorphins are thought to be involved in the relationship between physical activity and mood through inhibition of the central nervous system via opioid receptors. Similar to the action of morphine, this inhibition results in a sense of calm and improved mood (Peluso and Guerra de Andrade 2005). Lastly, a third reason suggested is that exercise may be able to reduce abnormalities in the hypothalamic-pituitary-adrenal axis, which are observed in people with major depressive disorder (aan het Rot *et al.* 2009). In these individuals, cortisol and corticotrophin levels increase immediately following exercise resulting in overall stress reduction with long-term training (aan het Rot *et al.* 2009). Other factors may include alterations in neurotropic factors, changes in neurocircuitry, or presently unknown mechanisms (aan het Rot *et al.* 2009).

The exact cause of fatigue among cancer survivors is not known, but many explanations have been postulated (Dimeo 2001). Exercise can influence several of these factors (Dimeo 2001). Decreased oxygen transport and utilization caused by cancer treatments can be improved with exercise through higher concentrations of oxidative muscle enzymes (Dimeo 2001). Exercise can reverse the effects of prolonged bed rest during hospitalization including reduced muscle mass, plasma volume, and cardiac output (Dimeo 2001). Exercise may also reduce fatigue by facilitating neuromuscular efficiency as well as enhancing lung function (Dimeo 2001).

Obviously there are also other physical responses to exercise that would improve someone's QOL. In healthy individuals, it has been shown that 12 weeks of training can improve aerobic fitness (maximum oxygen uptake) as well as reduce depression and tensions scores (Annesi 2003). Bartholomew *et al.* (2005) reported that even acute bouts of aerobic exercise can increase physical well-being and vigour scores. It is also important to remember that patients with cancer are at risk for the same co-morbidities as people without cancer. It is well established that physical activity reduces cardiovascular disease risk through improvement of risk factors such as blood pressure, body mass index, and lipid levels (Mora *et al.* 2007). Whatever the reason, it would be easy to compile millions of testimonials from those with and without cancer supporting the claim that exercise has improved one or more aspects of their health and life.

MAKING IT A REALITY

There are many challenges in implementing and sustaining exercise programs for cancer survivors. Most importantly, infrastructure and leadership *(Roadblocks to cancer cures [editorial]* 2004) will be needed to enable future success in promoting physical activity and facilitating ways for cancer survivors to engage in regular exercise. Leadership implies both organizational and financial components *(Roadblocks to cancer cures [editorial]* 2004). From a financial standpoint, cancer is big business. This holds true for both the academic and clinical worlds. The cost of cancer care to Canadian tax payers in 2004 amounted to almost $12 billion dollars (Canadian Cancer Society 2009). Operating costs of some Canadian research laboratories start at $50,000 and can each be up to half million dollars in total (Canadian Cancer Society 2009). Although this seems like an ample amount of money to set-up and run exercise laboratories and programs for people with cancer, much of the funding for cancer research and treatment is awarded to those working at the cellular or pharmacological levels. Oncologists, oncology nurses and family physicians are essential in ensuring that exercise is promoted among cancer survivors and that positions exist within our health care teams for exercise and rehabilitation specialists. Ideally, more time and money will be invested in programs that are focused on improving the health and well-being of cancer survivors through exercise.

HOW TO LIVE ACTIVELY WITH CANCER

Contrary to previous ideas on the management of cancer symptoms when patients were advised to rest in order to recover, we are now encouraging cancer survivors to participate in regular exercise programs (Lucia *et al.* 2003). This is especially true for overcoming feelings of fatigue (Lucia *et al.* 2003). Time constraints, lack of access to knowledge, and lack of motivation to start a program are three reasons that someone may not exercise. During these busy times, it may be helpful as clinicians to look at alternative ways to increase physical activity such as the 12 week telephone-based intervention described by Pinto *et al.* (Pinto *et al.* 2008). Researchers in this study made weekly phone calls to participants to encourage participation in bouts of moderate intensity physical activity (Pinto *et al.* 2008). The success of this type of intervention is evident at the 12 and 24 week follow-ups where participants reported enhanced QOL, decreased fatigue, and higher vigour (Pinto *et al.* 2008). This type of intervention is appealing because it is both convenient and cost-effective. To maintain interest in an exercise routine, a multidimensional rehabilitation program can be also used including activities such as individual exercises, sports, psycho-education, and information about exercise (van Weert *et al.* 2005).

It may be difficult to give specific exercise guidelines for cancer survivors to on a regular basis. Any number of scenarios could keep a cancer survivor from exercising, so patient "buy-in" on the positive effects of exercise is imperative. During or after treatment, there may be days when fatigue wins over exercise. Other days may be consumed by nausea and pain, and exercise is unthinkable. Also, depending on the cancer site, treatment and cancer stage, exercises may need to be targeted at certain body parts and avoided for others. Three components should be included in any exercise program: aerobic fitness, resistance training, and flexibility exercises (Courneya *et al.* 2004). The next step is to ensure that patients understand the proper techniques to the exercises that are being performed. Aim to complete low to moderate aerobic exercise, 3 to 5 times per week for at least 30 minutes. A full body strengthening program, targeting a patient's weakest areas is suggested and is to be performed 2 to 3 times per week. Daily flexibility exercises are also recommended, especially for people who are beginning a new training program.

CONCLUSION

We should be positive about finding a cure for cancer, but we should also be focused more on the holistic treatment of cancer survivors, which involves more than just medicines and technology. Unfortunately in some cases, patients are given chemotherapy and radiation and sent on their way until their next check-up. Cancer survivors are generally faced many physical and emotional challenges over the course of their disease and these changes can significantly reduce a patient's QOL. There is an immediate need to address the physical and mental health problems that are common in cancer survivors. It seems to me that our focus as a health care team should be to find a balance between conventional cancer treatments and other treatments such as physical rehabilitation, lifestyle modification and psychological guidance. By doing this we can optimize the health of each cancer survivor now and in the future. The role of exercise in cancer management is an area of study worthy of receiving more attention from our professional and financial allies. With proper leadership and support, this information could be used to change the QOL of many people living with cancer.

REFERENCES

aan het Rot M, Collins KA, Fitterling HL (2009) Physical exercise and depression. *Mount Sinai Journal of Medicine* 76(2):204-214.

Annesi JJ (2003) Sex differences in relations of cardiorespiratory and mood changes associated with self-selected amounts of cardiovascular exercise. *Psychological Reports* 93(3 Pt 2):1339-1346.

Barbaric M, Brooks E, Moore L, Cheifetz O (2010) Effects of physical activity on cancer survival: A systematic review. *Physiotherapy Canada* 62:25-34.

Bartholomew JB, Morrison D, Ciccolo JT (2005) Effects of acute exercise on mood and well-being in patients with major depressive disorder. *Medicine And Science in Sports and Exercise* 37(12):2032-2037.

Biceg D, Brown K, Ruddick M, Storey D, Wong C, Harris, SR (2009) Effects of exercise on quality of life in women living with breast cancer: A systematic review. *Breast Journal* 15(1):45-51.

Blanchard CM, Stein KD, Baker F, Dent MF, Denniston MM, Courneya KS, Nehl E (2004) Association between current lifestyle behaviors and health-related quality of life in breast, colorectal and prostate cancer survivors. *Psychology & Health* 19 (1):1-13.

Canadian Cancer Society's Steering Committee (2009) Canadian Cancer statistics 2009. Toronto, ON: Canadian Cancer Society.

Chen X, Zheng Y, Zheng W, Gu K, Chen Z, Lu W, Shu XO (2009) The effect of regular exercise on quality of life among breast cancer survivors. *American Journal of Epidemiology* 170(7):854-862.

Courneya KS, Friedenreich CM (2007) Physical activity and cancer control. *Seminars in Oncology Nursing* 23(4):242-252.

Courneya KS, Friedenreich CM, Quinney HA, Fields AL, Jones LW, Fairey AS (2003) A randomized trial of exercise and quality of life in colorectal cancer survivors. *European Journal of Cancer Care* 12(4):347-357.

Courneya KS, Jones LW, Fairey AS, Campbell KL, Ladha CM, Friedenreich CM, Mackey JR (2004) Physical activity in cancer survivors: implications for recurrence and mortality. *Cancer Therapy* 2:1-12.

Courneya KS, Mackey JR, Bell GJ, Jones LW, Field CJ, Fairey AS (2003) Randomized controlled trial of exercise training in postmenopausal breast cancer survivors: Cardiopulmonary and quality of life outcomes. *Journal of Clinical Oncology* 21(9):1660-1668.

Courneya KS, Vallance JK, McNeely ML, Karvinen KH, Peddle CJ, Mackey JR (2004). Exercise issues in older cancer survivors. *Critical Reviews in Oncology Hematology* 51(3):249-261.

Dagnelie PC, Pijls-Johannesma MCG, Lambin P, Beijer S, De Ruysscher D, Kempen GIJM (2007) Impact of fatigue on overall quality of life in lung and breast cancer patients selected for high-dose radiotherapy. *Annals of Oncology* 18(5):940-944.

Danhauer SC, Mihalko SL, Russell GB, Campbell CR, Felder L, Daley K, Levine EA (2009) Restorative yoga for women with breast cancer: Findings from a randomized pilot study. *Psycho-Oncology* 18(4):360-368.

De Backer IC, Schep G, Backx FJ, Vreugdenhil G, Kuipers H (2009) Resistance training in cancer survivors: A systematic review. *International Journal of Sports Medicine* 30(10):703-712.

Demark-Wahnefried W, Clipp EC, Morey MC, Pieper CF, Sloane R, Snyder DC, Cohen HJ (2004) Physical function and associations with diet and exercise: Results of a cross-sectional survey among elders with breast or prostate cancer. *The international journal of behavioral nutrition and physical activity* 1:16 doi:10.1186/1479-5868-1-16.

Dimeo FC (2001) Effects of exercise on cancer-related fatigue. *Cancer* 92(6 Suppl):1689-1693.

DiStasio SA (2008) Integrating yoga into cancer care. *Clinical Journal of Oncology Nursing* 12(1):125-130.

Doyle C, Kushi LH, Byers T, Courneya KS, Demark-Wahnefried W, Grant B, McTiernan A, Rock CL,Thompson C, Gansler T, Andrews KS, The 2006 Nutrition, Physical Activity and Cancer Survivorship Advisory Committee, & American Cancer Society (2006) Nutrition and physical activity during and after cancer treatment: An American Cancer Society guide for informed choices. *CA-A Cancer Journal for Clinicians* 56(6):323-353.

Funding cancer research (2009). Retrieved 02/07, 2010, from http://www.cancer.ca/canada-wide/cancer esearch/funding cancer research.aspx.

Galvao DA, Newton RU (2005). Review of exercise intervention studies in cancer patients. *Journal of Clinical Oncology* 23(4):899-909.

Galvao DA, Taaffe DR, Spry N, Joseph D, Newton RU (2010) Combined resistance and aerobic exercise program reverses muscle loss in men undergoing androgen suppression therapy for prostate cancer without bone metastases: A randomized controlled trial. *Journal of Clinical Oncology* 28(2):340-347.

Galvao DA, Taaffe DR, Spry N, Newton RU (2007) Exercise can prevent and even reverse adverse effects of androgen suppression treatment in men with prostate cancer. *Prostate Cancer and Prostatic Diseases* 10(4):340-346.

Hacker E (2009) Exercise and quality of life: Strengthening the connections. *Clinical Journal of Oncology Nursing* 13(1):31-39.

Hayes SC, Spence RR, Galvao DA, Newton RU (2009) Australian association for exercise and sport science position stand: Optimising cancer outcomes through exercise. *Journal of Science And Medicine In Sport* 12(4):428-434.

The history of cancer (2009). Retrieved 02/02, 2010, from http://www.cancer.org/docroot/CRI/content/CRI_2_6x_the_history_of_cancer_72.asp?sitearea=.

Karvinen KH, Courneya KS, North S, Venner P (2007). Associations between exercise and quality of life in bladder cancer survivors: A population-based study. *Cancer Epidemiology Biomarkers & Prevention* 16(5):984-990.

Lucia A, Earnest C, Perez M (2003) Cancer-related fatigue: Can exercise physiology assist oncologists? *Lancet Oncology* 4(10):616-625.

Markes M, Brockow T, Resch KL (2006) Exercise for women receiving adjuvant therapy for breast cancer. *Cochrane Database of Systematic Reviews* (4):CD005001.

McNeely ML, Campbell KL, Rowe BH, Klassen TP, Mackey JR, Courneya KS (2006) Effects of exercise on breast cancer patients and survivors: A systematic review and meta-analysis. *Canadian Medical Association Journal* 175(1):34-41.

Mead GE, Morley W, Campbell P, Greig CA, McMurdo M, Lawlor DA (2009) Exercise for depression. *Cochrane Database of Systematic Reviews* (3):CD004366.

Milne HM, Wallman KE, Gordon S, Courneya KS (2008) Effects of a combined aerobic and resistance exercise program in breast cancer survivors: A randomized controlled trial. *Breast Cancer Research and Treatment* 108(2):279-288.

Moadel AB, Shah C, Wylie-Rosett J, Harris MS, Patel SR, Hall CB, Sparano JA (2007) Randomized controlled trial of yoga among a multiethnic sample of breast cancer patients: Effects on quality of life. *Journal of Clinical Oncology* 25(28):4387-4395.

Mock V, Pickett M, Ropka ME, Muscari Lin E, Stewart KJ, Rhodes VA, McDaniel R, Grimm PM, Krumm S, McCorkle R (2001) Fatigue and quality of life outcomes of exercise during cancer treatment. *Cancer Practice* 9(3):119-127.

Mora S, Cook N, Buring JE, Ridker PM, Lee IM (2007) Physical activity and reduced risk of cardiovascular events: Potential mediating mechanisms. *Circulation* 116(19):2110-2118.

Mustian KM, Sprod LK, Palesh OG, Peppone LJ, Janelsins MC, Mohile SG, Carroll J (2009) Exercise for the management of side effects and quality of life among cancer survivors. *Current Sports Medicine Reports* 8(6):325-330.

Peddle CJ, Au HJ, Courneya KS (2008) Associations between exercise, quality of life, and fatigue in colorectal cancer survivors. *Diseases of the Colon & Rectum* 51(8):1242-1248.

Peluso MA, Guerra de Andrade LH (2005). Physical activity and mental health: The association between exercise and mood. *Clinics (Sao Paulo)* 60(1):61-70.

Pinto BM, Rabin C, Abdow S, Papandonatos GD (2008) A pilot study on disseminating physical activity promotion among cancer survivors: A brief report. *Psycho-Oncology* 17(5):517-521.

Pinto BM, Trunzo JJ (2004) Body esteem and mood among sedentary and active breast cancer survivors. *Mayo Clinic Proceedings* 79(2):181-186.

The quality of life model (2009). Retrieved 02/07, 2010, from http://www.utoronto.ca/qol/ concepts.htm.

Raghavendra RM, Nagarathna R, Nagendra HR, Gopinath KS, Srinath BS, Ravi BD, Patil S, Ramesh BS, Nalini R (2007) Effects of an integrated yoga programme on chemotherapy-induced nausea and emesis in breast cancer patients. *European Journal of Cancer Care* 16(6):462-474.

Roadblocks to cancer cures (Editorial) (2004). *Nature Medicine* 10(10):1003.

Roshanaei-Moghaddam B, Katon WJ, Russo J (2009) The longitudinal effects of depression on physical activity. *General Hospital Psychiatry* 31(4):306-315.

Segal RJ, Reid RD, Courneya KS, Malone SC, Parliament MB, Scott CG, Venner PM, Quinney HA, Jones LW, D'Angelo ME, Wells GA (2003) Resistance exercise in men receiving androgen deprivation therapy for prostate cancer. *Journal of Clinical Oncology* 21(9):1653-1659.

Segal RJ, Reid RD, Courneya KS, Sigal RJ, Kenny GP, Prud'Homme DG, Malone SC, Wells GA, Scott CG, Slovinec D'Angelo ME (2009) Randomized controlled trial of resistance or aerobic exercise in men receiving radiation therapy for prostate cancer. *Journal of Clinical Oncology* 27(3):344-351.

So WKW, Marsh G, Ling WM, Leung FY, Lo JCK, Yeung M, Li GKH (2009) The Symptom Cluster of Fatigue, Pain, Anxiety, and Depression and the Effect on the Quality of Life of Women Receiving Treatment for Breast Cancer: A Multicenter Study. *Oncology Nursing Forum* 36(4):E205-E214.

Strohle A (2009) Physical activity, exercise, depression and anxiety disorders. *Journal of Neural Transmission* 116(6):777-784.

Thorsen L, Courneya KS, Stevinson C, Fossa SD (2008) A systematic review of physical activity in prostate cancer survivors: Outcomes, prevalence, and determinants. *Supportive Care In Cancer* 16(9):987-997.

Vadiraja HS, Raghavendra RM, Nagarathna R, Nagendra HR, Rekha M, Vanitha N, Gopinath KS, Srinath BS, Vishweshwara MS, Madhavi YS, Ajaikumar BS, Ramesh BS, Nalini R, Kumar V (2009) Effects of a yoga program on cortisol rhythm and mood states in early breast cancer patients undergoing adjuvant radiotherapy: A randomized controlled trial. *Integrative Cancer Therapies* 8(1):37-46.

Vallance JK, Courneya KS, Plotnikoff RC, Yasui Y, Mackey JR (2007). Randomized controlled trial of the effects of print materials and step pedometers on physical activity and quality of life in breast cancer survivors. *Journal of Clinical Oncology* 25(17):2352-2359.

van Weert E, Hoekstra-Weebers J, Grol B, Otter R, Arendzen HJ, Postema K, Sanderman R, van der Schans C (2005) A multidimensional cancer rehabilitation program for cancer survivors: Effectiveness on health-related quality of life. *Journal of Psychosomatic Research* 58(6):485-496.

Visser MR, Smets EM (1998) Fatigue, depression and quality of life in cancer patients: how are they related? *Supportive Care in Cancer* 6(2):101-108.

What is cancer? (2010). Retrieved 02/07, 2010, from http://www.cancer.gov/cancertopics/ what-is-cancer.

PROC. N.S. INST. SCI. (2008)
Volume 45, Part 2, pp. 125-147

NOVA SCOTIAN INSTITUTE OF SCIENCE SESSION 2007-2008

PRESIDENT'S REPORT

This has been another busy and active year for the Institute promoting science in Nova Scotia. The highlights of the year are:

Our monthly lecture program attracted a good number of people especially the "*Climate Change Forum/Discussion*" in January at King's College. Many thanks to Sandra Nowlan and Brad Tucker for helping me develop the lecture program and to members who sent us their ideas. Also many thanks to Sandra for publicizing the talks widely to the news media which increased our attendances. Our Fall lectures were presented by Herschel Specter (RBR Consultants, New York), "*Nuclear Energy and the Post-Petroleum Future*", Rebecca Jamieson (Department of Earth Sciences, Dalhousie University), "*Baking the bedrock- why the Halifax Slates have "the Pits*", and Daniel O'Halloran (O'Halloran Campbell Consultants), "*In-Stream Tidal Power in the Bay of Fundy*". We also co-sponsored with Dalhousie's Department of Oceanography the 2007 Huntsman Award Public lecture on November 22 at Dalhousie University. Dr. Thomas Kiorboe from the Danish Institute for Fisheries Research, Charlottenlund, Denmark gave an interesting talk on "Sex and Death in the Ocean".

The winter/spring program started off in January with the "*Climate Change Forum/ Discussion*" organized and chaired effectively by Brad Tucker from the Discovery Centre. This was well attended and four panelists from universities and government spoke on different topics which sparked a lot of lively discussion. The February lecture was well presented by Dr. Christine Chambers (Departments of Pediatrics and Psychology, Dalhousie University and the IWK Health Centre) on the important topic of "*Childhood Pain*". In March Dr. Tanya Peckmann, Department of Anthropology, St. Mary's University, spoke about "*Identifying Human remains with Forensics*", and Dr. Jon Sweeney, Canadian Forestry Service, Fredericton spoke in April about "*The Brown Spruce Longhorn Beetle problem*", a very topical issue for local residents.

The *Proceedings* have been published under the very able editorship of Dr. James. E. Stewart for the past several years with the assistance of an editorial board. He informed us last year that he would like to step down and we are pleased to inform you that Dr. Peter Wells has been working with him as Associate Editor and will take over the Editorship later this year. We are very grateful to Jim for all the hard work he has done ensuring the *Proceedings* are published and to exacting standards. We entered into an exciting project with the Dalhousie University library to scan digitally the first 2 volumes of our Proceedings (1863 to 1870) into their recently launched digital repository. In December Michelle Paon and Sharon Longard gave us a presentation and Online Web demonstration of these scanned early volumes and we were impressed with the clarity and the hard work that had been put into this project. A proposal is being prepared for funding to continue with the digitization of Volumes 3 to 8 this summer. If this is successful we will be able to view these early volumes, and hopefully more in the future, on the web with a link to our website. This project will not only make these early works more accessible, but will also help minimize their slow physical deterioration.

Ken Adams kindly organized the annual Science Writing Competition again this year. Seven essays were received. The essay by Joseph Poissant (St. Mary's University Biology Graduate student) won the Graduate Student Award and the essay by Shane Journeay (Dalhousie Medical Student) won the Science Writing Category; certificates and cheques were presented at our April meeting.

We provided financial support again this year to the ten Regional Science Fairs in Nova Scotia and Sean Tibbets has continued to run the Mentorship program which matches students with working scientists. We also gave a small donation for a prize on a Nova Scotia Chemistry problem to the APICS/CIC Student Chemistry Conference to be held at St. Mary's University in May. Council approved revised By-Laws which are being submitted for approval by the general membership at the 2008 AGM. A copy of the original 1890 statute, when our Institute was incorporated by the Nova Scotia legislature, has been scanned into our website. The first two female scientists, Margaret S. Brown and Constance MacFarland, were appointed to our Nova Scotia Hall of Fame. The Institute celebrates its 150th Anniversary in 2012 and we are in the process of establishing a Planning Committee to develop ideas for celebrating this important event. If any general member would like to serve on this committee or has any ideas please contact our secretary, Linda Marks at marksl@mar.dfo-mpo.gc.ca. The Bedford Institute of Oceanography will also be celebrating its 50th Anniversary that year and we may be able to combine on some events.

Finally I would like to thank the Museum of Natural History for its continued support of our programmes, and all members of Council for their hard work during the year. Special thanks to Dr. Stuart Grossert for assisting me as Co-President this year during my absences and for his past and continuing dedication to the work of the Institute.

Respectfully submitted
Mary-Jane O'Halloran
Co-President
April 22, 2008

EDITOR'S REPORT
2007-2008

1) The 104-page issue of the Proceedings of the Nova Scotian Institute of Science Volume 44 Part 1 published in the summer of 2007 included papers providing a profile of the life and times of Donald Olding Hebb - Canada's greatest psychologist, a review of deepwater corals research in Atlantic Canada, and an account of the biological and environmental requisites for a successful shrimp trap fishery written as a tribute to Michael Newell the fisherman who developed the fishery. In addition, the issue contained several shorter articles (The Woodville Ice Cave, Records of the occurrence of a non-native fish and the student prize-winning paper on Rhodotorula glutinis by M. Jason MacDonald and Godwin D'Cunha.
2) As the photo-reproduction copies of the Flora of Nova Scotia produced in 2005 were almost sold out, a new photo-reproduction was undertaken. The original printing [Part 1 (1963 - 1964), Part II (1969)] was scanned and combined into a single large issue as before and the 100 copies were offered for sale in the summer of 2007. Again this is an exact copy of the original NSIS publication of the Flora of Nova Scotia; we have been particularly pleased with the quality of this scanning and the finished copy. Fortunately, the costs of the reproduction were low enough for this photo-reproduction to be sold for the same price ($35) as the previous 2005 volume.
3) Preparation of the PNSIS Volume 44 Part 2 is in hand. Currently a number of papers are being processed and publication is expected to be completed in the summer of 2008 in time for its circulation prior to the coming lecture season.

Respectfully submitted to the AGM
May 5, 2008
James E. Stewart
Editor PNSIS

TREASURER
MARCH 31, 2008

ASSETS:

Bank Account	$7,009.73		
Petty Cash	0.00		
	7,009.73		
Investments		56,130.81	
		63,140.54	
Account Receivable			
Membership			40.35
Tourism/culture Funding			1000.00
			64,180.89

LIABILITIES AND NET WORTH:

Accounts Payable	
Science Fairs	300.00
Writing competition	750.00
Treasurer expense	14.12
	$1064.12
Total Liabilities and Net Worth	**$63,116.77**

INVESTMENTS:

Cash Balance	42.77
CIBC Premium T-Bill (short-term)	16,192.04
CIBC Investment Certificate A @4.40% (due Apr 2008)	8,396.00
Laurention Bank Certificate A @3.675% (due May 2009)	10,000.00
Laurention Bank Certificate A @4.500% (due June 2010)	10,000.00
CIBC Investment Certificate A @5.05% (due Jun 2011)	11,500.00
	56,130.81

NOTES

Finances: The Institutes finances net worth is $63,116.77. Revenue included a NS tourism/culture grant ($1000) and ACCESS copyright for publication royalties amounting to $664.56.

Expenditures included donations/prizes of $1400 include $100 donations to each of 10 regional science fairs in Nova Scotia.

Membership: We collected $2720 in individual membership dues in 2007-2008. Membership sits at 145 including 5 Life members. Institutional membership dues amounted to $688.40.

Respectfully submitted to the AGM
May 1, 2008
H. Stephen Ewart

LIBRARIAN'S REPORT
2007/2008

(prepared for AGM May 5, 2008)

There are currently one hundred and eighty-five NSIS exchange partners. Two institutions, University of Utah and The Royal Irish Academy, cancelled their exchange program with us over the past year. The number of institutional members has increased by one and is now at twenty-eight. Invoices were sent out in January 2008 for institutional memberships and to date we have received payment for twenty-one renewals.

In October 2007 volume 44 part 1, of the *Proceedings of the Nova Scotian Institute of Science* was mailed to exchange partners and institutional members. In addition, we also did the mailing to personal members. Postal charges for distribution of the printed journal cost the Institute $1,317.74 in 2007/08.

The *Flora of Nova Scotia* by A.E. Roland was reprinted for a second time in the summer of 2007 in the one-volume format with spiral binding. One hundred copies were printed and the price remains at $35.00. Sales of past volumes of the *Proceedings* during 2007/2008 generated $477.50 in revenue. (See Appendix A (attached) for details.)

The Librarian submitted the required forms to Access Copyright for the 2007 repertoire payment to publishers. A cheque in the amount of $664.56 was received.

During the summer of 2007 volume 1, 1863-1866 and volume 2, 1867-70 of the *Proceedings of the Nova Scotian Institute of Science* were digitized and made available online through a digital initiative in the Dalhousie University Libraries. These volumes were deposited in DalSpace and can be viewed at http://dalspace.dal.ca/dspace and clicking on the Institutional Repository Pilot Project link. There are plans to continue this digitization project and volume 3 (1871-1874) to volume 8 (1890-1894) will be worked on during the summer of 2008.

Michelle Paon, a librarian from Killam Library at Dalhousie University who is Chair of the Institutional Repository Committee, gave a demonstration at the December 2007 meeting of NSIS Council of DalSpace and access to the digitized content of volumes 1 and 2 of the Proceedings.

The Provincial Legislative Librarian was contacted to ensure that the Act which incorporates the Nova Scotian Institute of Science in 1890 is not covered by copyright and can be posted on the Institute's website. It was determined that there are no copyright restrictions, so the Act has been scanned and added to the website.

Publications continue to be received regularly from our 185 active exchange partners and this material is added on an ongoing basis to the collection.

I would like to thank Carol Richardson and the Serials Department staff in the Killam Library who ensure that the NSIS Library operations continue to function smoothly.

Respectfully submitted
Sharon Longard
NSIS Librarian
April 11, 2008

Librarian's Report Appendix A

Sales of Proceedings May 2007 – March 2008

Qty	Date	Issue	Price
1	May 31, 2007	v.34, pt. ¾, 1984	$10.00 + $2.50 shipping & handling = $12.50
1	June 20, 2007	v.29, pt. 4, 1979	$7.50
1	June 20, 2007	v.30, pt. 1, 1980	$7.50 + $2.50 shipping & handling = $17.50
10	July 2007	The Flora of Nova Scotia	$35.00 x 10=$350.00
1	August 21, 2007	The Flora of Nova Scotia	
1	August 21, 2007	v. 23 pt. 1	$35.00 + $5.00 + $5.00 shipping & handling = $45.00
1	October 10, 2007	v.42, pt. 2	$15.00 + $2.50 shipping & handling = $17.50
1	March 7, 2008	The Flora of Nova Scotia	$35.00
			Total $477.50

NOVA SCOTIAN INSTITUTE OF SCIENCE
SESSION 2008-2009

Report of the President

During the past year, members of the Institute have actively engaged in furthering its mandate of promoting science in Nova Scotia. This has been achieved by:

- presenting a monthly program of public lectures given by expert Nova Scotian scientists,
- publishing the peer-reviewed Proceedings of the Nova Scotian Institute of Science,
- providing financial support for Regional Science Fairs,
- providing support for a number of Atlantic Provinces Council on the Sciences (APICS) undergraduate conferences by providing prizes for winning presentations
- maintaining a library
- running the annual scientific writing competition,
- developing and actively maintaining the Institutional web site at www.chebucto.ns.ca/Science/NSIS, with the great help of John Cordes.

During the past year, the lecture program of six public lectures was organized by David Richardson with the help of Ellen Louth and Sean Tibbets. All the lectures were held at the Nova Scotia Museum of Natural History and the Institute is indebted to the Museum for its continued support. We acknowledge the monthly help of David Christianson. The lectures involved speakers from both Dalhousie University and Saint Mary's University as well as from Wildwood laboratories. Feedback from the forty to fifty members attending each lecture was extremely positive. This was coupled with effective publicity organized by

Sandra Nowlan, resulting in the lectures not only being well-attended, but interviews being requested and broadcast by CBC radio. The programme was as follows:

Monday 6th October 2008
Kenneth Rockwood (Dalhousie University), “Life after 60 – is dementia or Alzheimer’s inevitable and/or treatable?”,

Monday 3rd November 2008
Anna Metaxas (Dalhousie University), “Hot spots of life in the Deep Sea”,

Monday 1st December 2008
Hugh Broders (Saint Mary’s University), “Life history and social ecology of Nova Scotian bats”,

Monday 2nd February 2009
Veronica Stinson (Saint Mary's University), "How to be a good eye-witness – memory and crime",

Monday 2nd March 2009
Glen Lesins (Dalhousie University), "Research at the top of the world – the changing climate and the International Polar Year",

Monday 6th April 2009
Dick Rogers, (Wildwood Laboratories) "To be a bee or not to be – threats to pollinators and consequences in Nova Scotia",

Monday 4th May 2009 Annual Dinner and AGM
Brian Hall (Dalhousie University) "What Charles Darwin was doing on the 4th of May"

The annual round table was held at the Scotia Bank Conference Theatre, Sobey building, Saint Mary's University on Monday 5th January 2009. The discussion with a panel of experts was on "Uranium and Gold extraction – can it be done safely in Nova Scotia". Short presentations were made by Marcos Zentilli (Dalhousie University), Michael Parsons (Natural Resources Canada), Paul Smith (Acadian Mining), Marc Lamoureux (Saint Mary's University). Questions and a general discussion followed. Over one hundred and fifty people attended the round table which was followed by a reception.

The Annual Dinner and AGM will be held on 4th May and to date 55 members have booked to attend.

Further Details of these NSIS meetings, can be found on the NSIS website.

For the past several years, the Proceedings have been published under the able editorship of James E. Stewart who has maintained a high standard. He has handed over the editorship to Peter Wells having seen the 2008 issue Volume 44 part 2 through to publication. The Institute is indebted to the Editor and to members of the Editorial Board for their services.

The early proceedings of the NSIS have been digitized and are now available for viewing and Dalhousie University, which houses the NSIS library, has agreed to digitize the next six volumes of the proceedings (1886-1910).

The annual Science Writing Competition was organized again this year by Robert Cook. Our congratulations to the two winners in the 2009 NSIS Student Essay Competition:

Gregory Hutton,
MLIS student in the School of Information Management,
Dalhousie University, Halifax,
"Understanding Influence of Scientific Information in the Digital Age: A Study of the Grey Literature of a United Nations Advisory Group",
and

Benjamin Langer,
BSc student in the Faculty of Science,
Dalhousie University, Halifax,
"The Middle Ground: why we can't save nature for nature"

Gregory and Benjamin have been invited to submit their papers for publication in the NSIS proceedings.

During the year, plans were initiated to celebrate the 150th anniversary of the NSIS in collaboration with the celebrations of the 50th anniversary of the Bedford Institute of Oceanography. A small committee has been established to work on the events. In recognition of the forthcoming 150th anniversary of the Nova Scotian Institute of Science, Joerg-Henner Lotze, Director, Humboldt Field Research Institute at Steuben Maine, has offered a scholarship to one member of the Nova Scotian Institute of Science for the forthcoming summer of 2009. This Scholarship will include the cost of tuition, accommodation and meals for a one-week Seminar. The winner of the scholarship will be announced at the AGM.

In other activities, the Institute has again provided financial support to the ten Regional Science Fairs in Nova Scotia, and the Institute cosponsored with the Ecology Action Centre the 2009 Symposium on Sable Island at Saint Mary's University.

In conclusion, members of the Institute are undoubtedly aware that the NSIS mission of presenting and promoting science, especially research, can only be achieved by continued activity on the part of members by serving on Council and by taking part in other activities of the Institute. As with all similar volunteer organizations, there is a need for younger members to become active as older members retire. The Institute has a long and proud history and will celebrate 150 years of promoting science to Nova Scotians in 2012. Few other Canadian organizations can boast this track record.

Finally, I thank all members of Council for their diligence and hard work during the past year.

Respectfully submitted,
David H.S. Richardson
April 28, 2009

EDITOR'S REPORT
2008-2009

Editorship of the Proceedings of NSIS changed hands in October, 2008. On behalf of the Institute, I thank and congratulate Dr. James (Jim) E. Stewart for the excellent job that he did as Editor since 2002, for his numerous written contributions to the journal, and for the assistance offered to me as incoming Editor over the past year.

The *Proceedings of the Nova Scotian Institute of Science*, Volume 44 Parts 1 and 2, were published in August 2007 and August 2008, respectively. Vol. 44(1) had five contributed papers, including a bibliographical overview of Donald Hebb, a distinguished psychologist from Nova Scotia; one prize winning student science paper; and obituaries of two prominent aquatic scientists from Halifax. Volume 44(2) had six contributed papers, including three on environmental conditions in Sydney harbour, NS, and two prize-winning student science papers. Both issues included reports of the Institute. Volume 44 was edited by Dr. Stewart.

Preparation of Volume 45, Part 1, is on-going, with two contributed papers submitted, two more in preparation, several more being solicited, and three prize winning science papers in hand. Publication of Volume 45(1) is expected to be late Summer 2009. There are a number of proposed submissions, both for specific papers and special issues over the next 3 years, and authors and special editors will be sought.

The Proceedings of the NSIS have a distinguished history and a bright future in a region noted for its scientific innovation and output. The journal is a major outlet for papers on the natural sciences of the Atlantic Provinces. It is my hope that the journal's profile will be enhanced in coming years, given the importance of science to the economic and environmental well being of our region. Indeed this has already begun through the Institute's efforts to place the Journal's contents onto its website.

Every member of NSIS and every reader should consider submitting articles on new research results, reviews, viewpoints and book reviews, to help continue the tradition of the Proceedings being a timely, salient and visible outlet for regional science in all of its dimensions. As well, suggestions from NSIS members and non-members as to the future role and future content of the Proceedings are always welcome.

Respectfully submitted to the AGM
May 4th, 2009
Peter G. Wells
Editor, NSIS

TREASURER
MARCH 31, 2009

ASSETS:			
Bank Account	7,962.39		
Investments	58,106.07		
TOTAL ASSETS			**66,068.46**
LIABILITIES AND NET WORTH:			
Accounts Payable Science Fairs		200.00	
Website CCN		50.00	
		250.00	
NET WORTH			**65,818.46**
Total Liabilities and Net Worth			**66,068.46**

INVESTMENTS:	
Cash Balance	6.44
CIBC Premium T-Bill (short-term)	6599.63
Laurention Bank Certificate A @3.675% (due May 2009)	10,000.00
Laurention Bank Certificate A @4.500% (due June 2010)	10,000.00
CIBC Investment Certificate A @5.05% (due Jun 2011)	11,500.00
CIBC Investment Certificate A @5.20% (due Oct. 2012)	20,000.00
TOTAL INVESTMENTS	**58,106.07**

Revenue

Membership Dues	
Individuals	$2,660.00
Institutions	508.47
AGM (2008)	1,362.00
Donations/Grant	2,310.00
Sales/Page charges	
Proceedings	2,378.03
Other	1,555.00
Income/Royalties	
Investment Income	2,051.04
Access Copyright Royalty	631.39
Bank Interest	4.05
	$13459.98

NOTES

Finances: The net worth of the Institute is $65,818.46. For this year, revenue included two grants of $1000.00 each from the Nova Scotia Department of Tourism and Culture as the grant for 2007- 2008 was not received until this budget year. The Institute also received $631.39 from ACCESS copyright for publication royalties.

Expenditures for donations and prizes were $2050.00. This included $100.00 donations to each of 10 regional Science Fairs in Nova Scotia, a $100.00 donation to the APICS Psychology Conference at Mount Saint Vincent University, and a $200.00 donation to the Annual Northeastern Biological Graduate Student Conference at Saint Mary's University.

Two writing competition awards were given; $500.00 for graduate and $250.00 for undergraduate.

Membership: The Institute has 110 active individual members including 7 life members and 2 student members. This year there were 10 new members and 2 new life members. Dues from individual members amounted to $2,660.00 and from institutional members $508.47.

Expenditures

Advertisement/Promotion	$357.62
AGM (2008)	1,312.63
Office supplies	25.32
Rent	165.00
Proceedings printing	2,577.59
Postage	3,868.12
Donations/Prizes	2050.00
	$10,356.28

Net: $3,103.70

Respectfully submitted to the AGM
May 4, 2009
Elaine D. McCulloch
Treasurer

LIBRARIAN'S REPORT
2008/2009

(prepared for AGM May 3, 2009)

There are currently one hundred and eighty-four NSIS exchange partners. One institution, Japan Academy, cancelled their exchange program with us over the past year. The number of institutional members has decreased by one and is now at twenty-seven. Bureau des echanges, Quebec, Canada cancelled their membership in February 2009. Invoices were sent out in January 2009 for institutional memberships and to date we have received payment for twenty-three renewals.

In November 2008, volume 44, part 2, September 2008 of the *Proceedings of the Nova Scotian Institute of Science* was mailed to exchange partners and institutional members. In addition, we also did the mailing to personal members. Postal charges for distribution of the printed journal cost the Institute $3,696.96 in 2008/09.

The *Flora of Nova Scotia* by A.E. Roland was reprinted for a second time in the summer of 2007 in the one-volume format with spiral binding. One hundred copies were printed and the price remains at $35.00. Sales of past volumes of the *Proceedings* during 2008/2009 generated $793.00 in revenue. (See Appendix A (attached) for details.)

The Librarian submitted the required forms to Access Copyright for the 2008 repertoire payment to publishers. A cheque in the amount of $631.39 was received.

During the summer of 2008 volumes 3-6 (1871-1886) of the *Proceedings of the Nova Scotian Institute of Science* were digitized and made available online through a digital initiative in the Dalhousie University Libraries. These volumes were deposited in DalSpace and can be viewed at http://dalspace.library.dal.ca/dspace/community-list. There are plans to continue this digitization project and volumes 7 (1886-1890) to volume 12 (1906-1910) will be worked on during the summer of 2009. At the April meeting, NSIS Council authorized the NSIS President, David Richardson, to sign a letter of *Copyright Clearance Permission* to enable the digitization of volumes of the *Proceedings* not in the public domain.

Publications continue to be received regularly from our 184 active exchange partners and this material is added on an ongoing basis to the collection. I would like to thank Carol Richardson and the Serials Department staff in the Killam Library who ensure that the NSIS Library operations continue to function smoothly.

Respectfully submitted
Sharon Longard
NSIS Librarian
April 30, 2009

Librarian's Report Appendix A

Sales of Proceedings May 2008 – February 2009

Qty	Date	Issue	Price
10	May 5, 2008	v. 25, pt. 2, 1959-1960	$5.00 x 10=$50.00 + $25.00 shipping & handling=$75.00
1		May 23, 2008	The Flora of Nova Scotia $35.00 x 2 = $70.00
1	May 26, 2008	v.25 Loucks	$5.00
14	July 24, 2008	Flora of Nova Scotia	$35.00 x 14=$490.00
2	August 12, 2008	Flora of Nova Scotia	$35.00 x 2=$70.00
1	September 2, 2008	v. 42, pt. 1	$22.00 + $2.50 shipping & handling = $24.50
1	December 11, 2008	v. I, pt.3, 1892-93	$5 x 3=$15.00 + $5.00 shipping & handling=$20.00
1	December 11, 2008	v. 9, pt.1, 1894-95	
1	December 11, 2008	v. 9, pt.4, 1897-98	
2	January 13, 2009	v.25 Loucks	$5.00 x 2=$10.00
1	March 26, 2009	v. 42 pt. 1 2002 (The Bras d'Or Lakes issue)	$22.00 + $6.50 shipping & handling =$28.50 ($23.25 US funds)
			Total $793.00

NOVA SCOTIAN INSTITUTE OF SCIENCE
SESSION 2009-2010

PRESIDENT'S REPORT

During the past year, members of the Institute have actively engaged in furthering its mandate of promoting science in Nova Scotia. This has been achieved by: presenting a monthly program of public lectures given by expert Nova Scotian scientists,

- publishing the peer-reviewed Proceedings of the Nova Scotian Institute of Science,
- providing financial support for Regional Science Fairs,
- providing support for a number of Atlantic Provinces Council on the Sciences (APICS) undergraduate conferences by providing prizes for winning presentations
- maintaining a library
- running the annual scientific writing competition,
- developing and actively maintaining the Institutional web site at http://www.chebucto.ns.ca/Science/NSIS/, with the great help of John Cordes.

During the past year, the lecture program of six public lectures was organized by Ron MacKay with the help of Ellen Louth and Sean Tibbets. All the lectures were held at the Nova Scotia Museum of Natural History and the Institute is indebted to the Museum for its continued support. We acknowledge the monthly help of David Christianson. The lectures involved speakers from Acadia University, Dalhousie University, St. Francis Xavier University and the National Research Council, Halifax. Feedback from the thirty to fifty members attending each lecture was positive. In addition we hosted a special lecture bye Peter Wadhams from Cambridge University in the UK to mark the 40th anniversary of the first circumnavigation of the Americas. Publicity for these events was organized by Robert Boudreau. The programme of lectures was as follows:

Monday 5th October 2009
Ulli Hoeger (Dalhousie University), "*Feel the force: mechanoreceptors and mechanoreception in Spiders*", 7:30 pm Nova Scotia Museum of Natural History

Monday 2nd November 2009
Jason Brown (Dalhousie University), "*The mathematics behind the music*", 7:30 pm Nova Scotia Museum of Natural History

Wednesday 18th November 2009
A Special Lecture to mark the Hudson 70 Anniversary by Peter Wadhams (Cambridge University), "*The first circumnavigation of the Americas*", 7:30 pm, Nova Scotia Museum of Natural History

Monday 7th December 2009
Karen Harper (Dalhousie University), "*Is the forest moving north? Consequences for northern communities*", 7:30 pm Nova Scotia Museum of Natural History

Monday 4th January 2010
Panel discussion "*Land protection in Nova Scotia - How do we get to 12%?*", Scotia Bank Conference Theatre, Sobey Building, St. Mary's University. .

Monday 1st February 2010
Patrick McGinn (National Research Council), "*Perspectives and outlook for bioenergy: from fossil fuels to holy grails*", 7:30 pm Nova Scotia Museum of Natural History

Monday 1st March 2010
Karine Le Bris (St. Francis Xavier University), "*Greenhouse effect and ozone depletion-monitoring: trace gas-detection by spectroscopic techniques*", 7:30 pm Nova Scotia Museum of Natural History

Monday 5th April 2010
Steve Mockford (Acadia University), "*Genetics, scale, and conservation: reptiles at risk in Nova Scotia*", 7:30 pm Nova Scotia Museum of Natural History

Monday 3rd May 2010
NSIS Annual Dinner and AGM (Dalhousie University Club). After-dinner speaker Sonya Dehler (Geological Survey of Canada, Natural Resources Canada), "*Using large earthquakes to study local geology*".

The annual round table was held at the Scotia Bank Conference Theatre, Sobey building, Saint Mary's University on Monday 4th January 2010. The discussion with a panel of experts was on Land Protection in Nova Scotia – How do we get to 12%? Short presentations were made by David Mackinnon (NS Department of Environment and Labour), Andrea Doucette (New Page, Port Hawkesbury), Dennis Garratt (Nova Scotia Nature Trust) and Elder Albert Marshall (Eskasoni First Nation, Unama'ki Institute of Natural Resources). Questions and a general discussion followed. About fifty people attended the round table which was followed by a reception

A second round table was held on Wednesday 3rd March for which the NSIS was one of the sponsors. This was the Sixth Annual Public Meeting on Sable Island held in theTheatreAuditorium, McNally Building Saint Mary's University and included three illustrated talks by Ian McLaren, (Dalhousie University), Bill Freedman (Dalhousie University) and Zoe Lucas (Naturalist and Sable Island resident). Short presentations followed by Kevin McNamee (Director of Parks Establishment, Parks Canada), Kevin Davidson Canadian Wildlife Service) and by Mark Butler (Ecology Action Centre) on the future status of Sable Island.

A Question and Answer Session was followed by a Reception. This was a lively meeting attended by three hundred people.

The Annual Dinner and AGM was held on 3rd May at the Dalhousie University Club. Around 40 members attended and enjoyed both he dinner and the speech by Sonya Dehler on *"Earthquakes and using them to study local geology"*

The Proceedings are now under the editorship of Peter Wells who plans to have two issues produced during 2010 calendar year. The Institute is indebted to the editor and to members of the Editorial Board for their services.

The early proceedings of the NSIS have been digitized and are now available for viewing and Dalhousie University which houses the NSIS library has digitized the proceedings from 1886-1910 and we hope will soon make more recent volumes available. Further Details, can be found on the NSIS website

The annual Science Writing Competition was organized again this year by Robert Cook. Our congratulations to the winners in the 2010 NSIS Student Essay Competition:

Gregory Hutton,
MLIS student in the School of Information Management,
Dalhousie University, Halifax,
"Understanding Influence of Scientific Information in the Digital Age: A Study of the Grey Literature of a United Nations Advisory Group", and

Benjamin Langer,
BSc student in the Faculty of Science,
Dalhousie University, Halifax,
"The Middle Ground: why we can't save nature for nature"

Gregory and Benjamin have been invited to submit their papers for publication in the NSIS proceedings.

Plans are underway to celebrate the 150th anniversary of the NSIS. We have submitted proposals to Canada post for a special stamp to celebrate this event. In addition we hope that the application from SRES (Dalhousie University) with the support from the NSIS for the 2012 Killam lectures to celebrate our anniversary via a series of leading science speakers will be successful. We are also collaborating with the Bedford Institute of Oceanography who celebrate their 50th anniversary in 2012. We hope that the proceedings of their special lectures in 2010 will be published in the NSIS Proceedings. A small committee has been established and is continuing to work on these events.

In relation to the Anniversary and future of the NSIS Council held a Special Planning day-long planning meeting on the 14th March, 2010. This focused on improving publicity for NSIS Events, recruiting new members of the NSIS both in HRM and further afield, encouraging members to submit papers for publication in the proceedings and discussions with respect to events for the 150th anniversary.

In other activities, the Institute has again provided financial support to the ten Regional Science Fairs in Nova Scotia. The NSIS responded to a request for funding from École Rose-des-Vents, Greenwood NS. A team of six students from the school to represent the province at the First Lego League Robot Programming Competition 14th – 17th April in Atlanta, Georgia. A contribution of $200 was provide to assist the team with expenses

In conclusion, members of the Institute are undoubtedly aware that the NSIS mission of presenting and promoting science, especially research, can only be achieved by continued activity on the part of members by serving on Council and by taking part in other activities of the Institute. As with all similar volunteer organizations, there is a need for younger members to become active as older members retire. The Institute has a long and proud history and will celebrate 150 years of promoting science to Nova Scotians in 2012. Few other Canadian organizations can boast this track record.

Finally, I thank all members of Council for their diligence and hard work during the past year.

Respectfully submitted,
David H.S. Richardson
May 20 2010

EDITOR'S REPORT
2009-2010

The three Maritime Provinces of Canada are blessed with a wealth of universities, research institutes, government departments (provincial and federal), industries and consulting firms dedicated to basic and applied research in many fields. This mass of talented people and state of the art facilities is building upon its international recognition in fields such as marine science, biotechnology, the environmental and health professions, and computer and information sciences, and underpins the region's economic and environmental security. It puts the Maritime Region into a strong position to address looming new challenges requiring a strong knowledge base – climate change, management of living resources, health issues such as cancer and obesity, coastal protection and conservation, pollution control, quality living in urban regions, quality of life balance, and others. A dynamic scientific enterprise, especially one encouraging and employing young scientists in all fields, offers promise of a bright future.

The Nova Scotian Institute of Science (NSIS) is almost 150 years old. It helps to support this enterprise of science serving society through its annual program of seminars, support for young scientists, and the Journal. As you read the pages of the current issue, and access the website of the Society (www.chebucto.ns.ca/Science/NSIS/), please reflect on the role of science in Maritime society, and its latest developments. We would like to hear from you, have you participate in the Society's program, and especially have you contribute to these pages.

The Journal has a new and committed Editorial Board. Its members will help direct the new PNSIS ship on the journey of addressing the scientific and societal challenges of the new century, and reporting our best science. We are building on a proud foundation for the Journal, thanks most recently to the fine work of the past Editor, Dr. James (Jim) Stewart.

The NSIS would like to see a diversity of articles in the Proceedings, ranging from papers of original research from across the disciplines, to viewpoint articles, reviews of work in current fields of research, book reviews, and letters to the Editor. An Editorial may even appear from time to time! With your help and input, the Proceedings can continue to be a dynamic outlet for new and important information in Maritime science. Articles are especially encouraged from the natural and engineering sciences, as well as from the health professions, but papers in any of the natural and related social sciences (e.g. history of science, environmental economics, information science and management) of Nova Scotian or Maritime interest will be considered.

The NSIS looks forward to celebrating its 150th Anniversary in 2012, with special issues of the Proceedings planned for that year. Please read the journal, become a contributor, and join in this exciting journey of documenting scientific discovery and progress in Nova Scotia and the Maritimes.

Peter G. Wells, Ph.D., Editor
David H.S. Richardson, Ph.D.
Associate Editor and President, NSIS

TREASURER
MARCH 31, 2010

ASSETS:		
Bank Account	9,954.75	
Investments	60,598.90	
TOTAL ASSETS		**70,553.65**
LIABILITIES AND NET WORTH:		
Accounts Payable		
Science Fairs	200.00	
Honorarium	200.00	
	400.00	
Net Worth		**70,153.65**
Total Liabilities And Net Worth		**70,553.65**

INVESTMENTS:	
Renaissance High Interest Savings Account	8,798.90
Laurention Bank Certificate A @4.500% (due June 2010)	10,000.00
CIBC Investment Certificate A @5.05% (due Jun 2011)	11,500.00
CIBC Investment Certificate A @5.20% (due Oct. 2012)	20,000.00
National Bank of Canada Certificate A@2.900% (due May 2013)	10,300.00
TOTAL INVESTMENTS	**60,598.90**

NOTES

Finances: The net worth of the Institute is $70,153.65. For this year, revenue included a grant of $1000.00 from the Nova Scotia Department of Tourism and Culture. The Institute also received $507.26 from ACCESS copyright for publication royalties.

Expenditures for donations and prizes totalled $2000.00. This included $100.00 donations to each of 10 regional Science Fairs in Nova Scotia; a $50.00 donation to the APICS Undergraduate Chemical Conference at Saint Francis Xavier University; and a $200.00 donation to École-Rose-des-

Vents, the winner of the FIRST LEGO League Competition in Nova Scotia and chosen to attend the World Festival in Atlanta, Georgia.

Two writing competition awards were given; $500.00 for graduate and $250.00 for undergraduate.

Membership: The Institute has 99 active individual members including 7 life members and 1 student member. This year there were 7 new members. Dues from individual members amounted to $1,890.00 and from institutional members $370.00.

Respectfully submitted to the AGM
May 3, 2010
Elaine D. McCulloch
Treasurer

Revenue	
Membership Dues	
Individuals	$1,890.00
Institutions	370.00
AGM (2009)	2,336.00
Donations/Grant	1,160.00
Sales/Page charges	
Proceedings	51.94
Other	665.00
Other	
Cancelled cheque	50.00
Income/Royalties	
Investment Income	2,447.32
Access Copyright Royalty	507.26
Bank Interest & Exchange	1.81
	$9,479.33
Expenditures	
Advertisement/Promotion	$139.64
AGM (2009)	2,214.35
Office supplies	20.99
Rent	165.03
Postage	49.64
Donations/Prizes	2000.00
Honoraria	600.00
	$5,189.65
	Net: $4,289.68

LIBRARIAN'S REPORT
2009/2010

(prepared for AGM May 3, 2010)

There are currently one hundred and eighty-three NSIS exchange partners. One institution, Exchange Centre for Scientific Literature, Helsinki, Finland cancelled their exchange program with us over the past year. The number of institutional members has decreased by one and is now at twenty-six. Department of Fisheries & Oceans Library, Atlantic Fisheries Gulf Region cancelled their membership in May 2009. Invoices were sent out in January 2010 for institutional memberships and to date we have received payment for fifteen renewals.

To date no issue of the *Proceedings of the Nova Scotian Institute of Science* has been published in the 2009/10 year, so no mailing to exchange partners and institutional members has taken place.

Sales of past volumes of the *Proceedings* during 2009/2010 generated $693.00 in revenue. (See Appendix A (attached) for details.) There are 43 copies of the *Flora of Nova Scotia* by A.E. Roland on hand @ $35.00 each.

The Librarian submitted the required forms to Access Copyright for the 2009 repertoire payment to publishers. A cheque in the amount of $507.26 was received.

During the summer of 2009 volumes 7-12 (1886-1910) of the *Proceedings of the Nova Scotian Institute of Science* were digitized and made available online through a digital initiative in the Dalhousie University Libraries. These volumes were deposited in DalSpace and can be viewed at http://www.library.dal.ca/collections/digitalcollections/nsis. There are plans to continue this digitization project and volume 13 (1910-1914) onwards will be worked on during the summer of 2010.

Publications continue to be received regularly from our 183 active exchange partners and this material is added on an ongoing basis to the collection. I would like to thank Carol Richardson and the Serials Department staff in the Killam Library who ensure that the NSIS Library operations continue to function smoothly.

Respectfully submitted,
Sharon Longard
NSIS Librarian
March 22, 2010

Librarian's Report Appendix A

Sales of Proceedings May 2009 – February 2010

Qty	Date	Issue	Price
1	May 2009	v.26 pt. 2	$35.00
17	July 2009	v.26 pt. 2	$35.00 x 17 =$ 595.00 (Pierre Taschereau's Biology class)
1	July 2009	v.26 pt. 2	$35.00
1	October 2009	v. 43, pt.2	$16.00
1	February 2010	v.27, suppl. 3, 1975	$5.00 + $7.00 shipping & handling = $12.00
			Total $693.00

Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp.148-154

INDUCTEES TO THE NS SCIENTIFIC HALL OF FAME

Carlyle Smith Beals 2008

Born: 29 June, 1899
Died: 2 July 1979
Field: Astronomy

Carlyle S. Beals (1899-1979) served as the assistant director of the Dominion Astrophysical Observatory in Victoria, and later as the Dominion Astronomer in Ottawa. His research focussed on the study of spectrum emission lines of hot stars, as well as the nature of gas clouds in interstellar space. He also pursued an interest in geophysics, investigating and identifying ancient meteorite craters. Beals retired in 1964 and died in 1979 in Ottawa at the age of 80.

Biography

Carlyle Beals was born in 1899 Canso, Guysborough County, Nova Scotia He obtained his bachelor's degree in 1919 from Acadia University in Wolfville, and he enrolled in doctoral studies in 1921 at Yale University in the United States, but his failing health prevented him from pursuing this goal. He enrolled instead at the University of Toronto and obtained his Master's degree in 1923. He then taught for one year at a school, and enrolled in the University of London, England, in 1922. Four years later he obtained his doctoral degree in physics.

Career

After one year as a professor at Acadia University, Dr. Beals joined the staff of the Dominion Astrophysical Observatory in 1927. He was appointed Dominion Astronomer, Ottawa, in 1947, a position from which he retired in 1964. Carlyle Beals received many awards for his work in astronomy, geophysics and administration, including the Order of Canada. Asteroid 3314 and a lunar crater were named in his honour. In 1981, the Astronomical Society of Canada created the Carlyle S. Beals Award, given every two years to a Canadian astronomer, or an astronomer working in Canada, in recognition of their outstanding achievement in research. Dr. Beals had a long and distinguished career in astronomy, holding a B.A. degree from Acadia University, an M.A. from the University of Toronto, and a Ph.D. and D.Sc. from London University. Dr. Beals also received the honorary degree of D.Sc. from Acadia University, University of New Brunswick, Queen's University, and the University of Pittsburgh.

He was a Fellow of the Royal Society and a Fellow of the Royal Society of Canada, and was President of Section III of the latter. He also served as President of the American Astronomical Society and as President of the Royal Astronomical Society of Canada.

J.Cordes

Dr. Constance Ida MacFarlane

Born: 1904
Died: 2000
Field: Botany, specializing in seaweeds

Constance Ida MacFarlane was one of a few women scientists working in Nova Scotia in the early 1900's. Her work on the ecology of seaweeds influenced the commercial harvesting in the region and elsewhere. She served as Director of the Seaweeds Division, Nova Scotia Research Foundation from 1949-1970. Her contributions through publication of books and articles researched an international audience and her legacy in science continues through awards in her honour at Dalhousie, Acadia and UPEI.

Biography

Dr. Constance Ida MacFarlane was born in Charlottetown, PEI in 1904. She graduated from Prince of Wales College in 1924 and Dalhousie University (BA, 1929, M.Sc. 1931) and then pursued post-graduate studies on marine algae at the University of Liverpool, England. From 1949-1970, Miss MacFarlane was Director of the Seaweeds Division of the Nova Scotia Research Foundation from 1949-1970

Career

Constance MacFarlane was Director of the Seaweed Division of the Nova Scotia Research Foundation. She also taught a course in marine algae at Acadia University for twenty years during the time she was at the research foundation. Throughout her career, Constance MacFarlane considered herself primarily a teacher, whether her students were in university, fishermen, harvesters, government officials, lawyers or industrialists. She wrote, "...as in the way with teaching, I also learned much from my students particularly the fishermen who, of necessity, are resourceful people." She established awards at several universities, two of which are dedicated to the memory of her father, Henry Havelock MacFarlane. These include *The Constance MacFarlane Scholarship* at Dalhousied University. This endowment fund provides a scholarship to a deserving student in the second or subsequent year of the Honours programme in either biology or marine biology. The *Dr. Constance Ida MacFarlane Prize* at the University of Prince Edward Island is a prize for a Biology student, preferably graduating, with particular botanical interests. The *Dr. Constance Ida MacFarlane Scholarship* at the same university is an award for a Biology major or honours student and preference is given to students with marine botanical or botanical interests. Finally, the *Constance I. MacFarlane Book Prize in Marine Biology* at Acadia Universityis is awarded each spring on the recommendation of the Head of the Biology Department to a student with special interest and promise in the field of marine algae.

Collections

Constance was internationally recognized for her research into the ecology and distribution of seaweeds, which was fundamental to the industrial development of seaweed in the Atlantic Provinces. Her hobby was collecting seaweed from around the world. She bequeathed her huge collection of dried specimens to the Nova Scotia Museum of Natural History in Halifax and her papers to the Nova Scotia Archives.

Publications: 7 articles and 6 books including:

MacFarlane, Constance. 1952. A survey of certain seaweeds of commercial importance in southwest Nova Scotia *Canadian Journal of Botany* 30(1):78-97.

MacFarlane, Constance and **Hugh P. Bell.** 1933. Observations of the seasonal changes in the marine algae in the vicinity of Halifax, with particular reference to winter conditions. *Proceedings of the Nova Scotia Institute of Science.* 18:134-176

Young, E. Gordon and **C. MacFarlane.** 1962. Seaweed Symposium. Science 20: 267-274. The above article is an edited version of that entitled SCHOOL STREET HOUSE, BIRTHPLACE OF WORLD RENOWNED MARINE BIOLOGISTto be found at www.schoolhousestreet.com.

Margaret Sibella Brown
A Nova Scotian Bryologist

Born: March 2, 1866
Died: Nov. 15, 1961
Field: Botany, specializing in bryophytes

Margaret Sibella Brown achieved an international reputation for her work on the taxonomy and ecology of bryophytes (mosses and liverworts) at a time when women in science were relatively rare. Her foray activities extended well beyond Nova Scotia, and the region, as she developed her expertise working with other internationally recognized botanists. The impact of her work in Nova Scotia is notable given that she identified, preserved and catalogued an extensive collections of these poorly known plants. Her collections are now housed at the E.C. Smith Herbarium at Acadia University as well as other herbaria in NS and NB, as well as other important repositories in Canada, England and the United States.

Brown received an honorary MA from Acadia University in 1950, when she was 84 years old.

Biography

Margaret Sibella Brown, born on March 2, 1866 to Richard and Barbara Brown of Sydney Mines, Nova Scotia, shared her arrival into this world with sister Elizabeth. The twins were the eldest to three other siblings, Anne, Richard, and Lillian. Their father, Richard, was the general manager of Cape Breton's Sydney Coal Mines and the first elected mayor of Sydney Mines. Margaret was educated at the Anglican School for Girls in Halifax and the Anglo-German Institute finishing school in Stuttgart, Germany (1883-84), Margaret continued her studies in London, receiving tutelage in French and china painting. She returned to Nova Scotia in 1885, and attended the Victoria School of Art and Design where she later served as directorate on the board and became an instrumental member of the education committee. In 1934, Margaret received an honorary diploma from the institution, recognizing her efforts to secure funds for the new campus, the *Nova Scotia College of Art and Design*.

Margaret was elected president of The Halifax Floral Society of Nova Scotia and at the time of her death at the age of 95 she was the oldest living member of the *Nova Scotian Institute of Science*. She was also a member of the Sullivant Moss Society, currently known as the American Bryological and Lichenological Society.

Career

Margaret's bryological career began under unusual circumstances during World War I while in the position of honorary secretary of the Halifax Branch of the Canadian Red Cross Society. Dr. Robert Thomson of the University of Toronto asked Margaret to organize the Nova Scotia contribution to the collection of Sphagnum moss for use in the production of field dressings and ambulance mattress stuffing. This experience rekindled a previous interest in botany. At the end of the war she was able to pursue her interest in Bryology. Her mentors were Dr. Nathaniel L. Britton and his wife, bryologist Elizabeth G. Britton, founders of the New York Botanical Gardens. As Mrs. Britton's assistant, Margaret traveled with them on various expeditions, including one to Puerto Rico and Trinidad in 1922. Margaret scoured Nova Scotia for specimens and also collected samples elsewhere in Canada including the Bruce Peninsula, Ontario and the Selkirk Mountains in British Colombia. She also undertook scientific expeditions to Spain, the French Riviera, and Jamaica where she often wintered.

Margaret corresponded and exchanged moss collections with many eminent bryologists across the globe.

In 1932, Miss Brown published her first paper in The Bryologist, in which she described a new species of moss, Entosthodon neoscoticus M.S. Brown, collected from rocks at Peggy's Cove, Nova Scotia. Her most comprehensive work is the "Liverworts and Mosses of Nova Scotia" in which she documents 127 hepatics and 367 mosses for the province (Proceedings of The Nova Scotian Institute of Science, 1936, Vol. 19, pt. 2, pp.161-198). Six more publications followed in The Bryologist. One article was entitled, "The Mosses from Syria" and is based on material collected there by W.B. Evans.

In 1950, encouraged by her student John Erskine, Margaret donated her bryophyte collection to Acadia University. In recognition of the significance of her gift, on May 16th of that same year, Acadia conferred an Honorary MA upon Margaret, who was in her 84th year. Never having sought a college degree, she resolutely declined Acadia's offer of an honorary PhD, accepting the MA instead. John Erskine wrote of Margaret's influence on the botanical community of Nova Scotia in An Introduction to the Moss Flora of Nova Scotia (1968) stating, "During the next twenty five years [ca. 1922-1951] Miss Margaret S. Brown carried on the work [the study of Nova Scotia mosses], spending her summers in many parts of the province, and anyone who has learned anything about mosses in this quarter-century owes much to her knowledge and kindness."

Collections

The Margaret S. Brown collection at the E.C. Smith Herbarium at Acadia University consists of 1779 mosses, 858 hepatics and 53 lichens. Margaret's specimens are also deposited at the *British Museum, Kew Gardens, New York Botanical Gardens, Dalhousie University* (flowers and grasses), the *New Brunswick Museum*, the *Nova Scotia Museum of Natural History* and the *Devonian Botanical Garden* at the University of Alberta.

Acknowledgements The above is an edited version of an article prepared for the Bryophyte Workshop, July 3-5, 2005 by Jean Timpa with the assistance of Karla Kuklis, Amy James and Shawna Singleton. The original article can be found on line at http://herbarium.acadiau.ca/projects/

2140 10

NOVA SCOTIAN INSTITUTE OF SCIENCE COUNCIL 2009 – 2010

esident: David Richardson
ce-President: Ron MacKay
st President: Mary-Jane O'Halloran
st President: Stuart Grossert
cretary: Linda Marks

Treasurer: Elaine McCulloch
Editor: Peter G. Wells
Librarian: Sharon Longard
Webmaster: John Cordes
Publicity: Robert Boudreau

uncillors: Robert H. Cook (Writing Competition Coordinator), Charlene MacDonald (NS Science Teachers' Rep), Michelle Paon (2012 Sesquicentennial Committee), Henry (Hank) Bird, Angelica Silva, Doug Strongman

udent Representative: Chris Curry (Dalhousie)

servers: David Christianson (Nova Scotia Museum), Rebecca (Becky) MacKenzie (Discovery Centre),Tom Sephton (BIO 2012 Anniversary Celebrations Committee), Charlene MacDonald (Science Teachers' representative)

Instructions to Authors

pers may be submitted in either English or French and should be sent electronically to the itor at (nsis@dal.ca). The title should be followed by names, addresses and E mails of all thors. An abstract of up to 200 words should follow. As appropriate, sections devoted to roduction, methods, results, discussion, conclusions and references should be included. nadian spelling and SI units should be used wherever possible. There is currently a page arge of $25 per page but this will not be levied if all authors are NSIS members (Membership sts $25 per year for regular members and $10 year for students.) Tables, figures and black d white photographs may be included and will be published without an extra charge. Pubation of colour figures in any hard copy of the journal will incur a charge that must be borne the author and will likely be in the range of $500 per plate which may be a single photo or collage. All tables and illustrations should have a title and a self-explanatory legend.

efer to back issues of the Journal for general layout of a paper. Pages should be numbered. eferences should be in alphabetical order and give the full title of the journal and issue mbers where appropriate, thus:

elsen, K.J., & France, D.F. (1995) The influence of adult conspecifics and shore level on cruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine ology and Ecology* 188 (1):89-98.

ushing, D. & Walsh J. (1976) The Ecology of the Seas. W. B. Saunders Company, Toronto.

e, G.F. (1975) Role of hydrous metal oxides in the transport of heavy metals in the envinment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, xford, pp. 137-147.

ersonal Communication: Smith A.J. (2001, pers. comm.) in text.

ebsite Citation: Author (year) title, URL and date accessed.

uthors are responsible for correcting and returning proofs promptly. Authors will be provided ith a PDF of their paper, free of charge. NSIS members receive a hard copy of the Proceedgs as part of their annual membership. Copies of Special Issues of the NSIS proceedings ay also be purchased from NSIS at a charge established by the NSIS. See the NSIS website tp://www.chebucto.ns.ca/Science/NSIS/ for details.

PROCEEDINGS
of the
Nova Scotian Institute of Science
HALIFAX, NOVA SCOTIA

Volume 45 2010 Part 2

R.M. Murphy
Waiting for a cure: balancing medicine and quality of life for people living with cancer 1

NSIS Reports from Council Officers
(Sessions 2007-2008, 2008-2009, 2009-2010)
President's report, Editors Report, Treasurers Report
Librarians Report 1

Inductees to the NS Scientific Hall of Fame
Carlyle Smith Beals 2008
Constance Ida MacFarlane
Margaret Sibella Brown 1

The Proceedings of the Institute have been published since 1863. Back issues a
available from the Institute's library housed in the Killam Library, Dalhousie Univers
Halifax, and early issues up to 1910 are available on-line at:

http://dalspace.library.dal.ca/dspace/handle/10222/11192

ISSN 0078-2521

MCZ ERNST MAYR LIBRARY
3 2044 118 663 632